Summary

This report forms the completion of a thesis at Vanderlande Industries B.V., as part of the study Systems Engineering, Policy Analysis and Management at the Delft University of Technology. Vanderlande Industries, supplier of material handling systems, wants to enlarge her market share in baggage handling systems (BHS) and is therefor compelled to reconsider the current design process in the sales phase. This formed the lead for the start of this research, which was aimed on the following objective:

Creating a situation at Vanderlande Industries in which engineers design Baggage Handling System solutions, based on clear justification of design choices which are well tuned to the total set of requirements and wishes of all stakeholders.

Based on the implications of this objective the current situation was analysed to define the occurring problems that block the realisation of the objective. These problems were identified and can be summarised by:

1) Too little attention for the decision process of the customer about which supplier will be awarded with a BHS contract
2) Too little teamwork regarding information processing and evaluation
3) Inadequately justification including documentation of BHS concept design choices

After verification of the problems with participation of involved employees, solution directions were found and elaborated by consulting literature and discussing subjects with employees. These solution directions are packed together and integral elaborated into a new design methodology, supported by new tools.

The new design methodology is based on the thought of a better mix between technical aspects and social aspects to realise a better understanding of the real requirements on a BHS concept in the sales phase at Vanderlande Industries, by:

1) Getting grip on the decision process of the customer (corresponding activities are lobby, stakeholders and requirements analysis and feedback elicitation)
2) Teamwork regarding information processing and evaluation (corresponding activities are team formation and team based evaluation of information and designed BHS concepts)
3) Integral justification of the design choices including documentation (corresponding activities are (quantified) justification documentation and simulation and costs studies)

The main aspects that are advised to control the new design approach, are the introduction of a process manager and the division and documentation of responsibilities during the design effort. To support the employees in their activities, three tools are introduced:

1) The design choices justification tool (developed, a MS-Excel document containing templates for the stakeholders network analysis, the requirements analysis and the documentation of a BHS concept including justification of the design choices)

2) The simulation tool (existing software of Enterprise Dynamics including the BAXSIM library, graphical oriented simulation package including BHS objects)
3) The cost calculator (developed, based on the simulation tool, containing different elements of life cycle costs with the emphasis on the investment costs)

Evaluation sessions with employees of different departments and Customer Centres showed appreciation and support for the suggested methodology and tools. It is broadly recognised that introduction will help reaching the objective, which implies improvement of the professional appearance, the design process efficiency and the competitiveness of Vanderlande Industries.

The new methodology and tools are not tested in a real situation because of the limited time available for this thesis. Therefor, Vanderlande Industries is advised to use them in pilot projects first followed by an evaluation, before implementation in the entire organisation.

As a result of this thesis, recommendations are made towards Vanderlande Industries concerning further research or activities. The following recommendations focus on efficiency improvements:

- Tailoring of the methodology and tools for usage by other disciplines (such as Warehousing & Distribution and Express Services Industry)
- Keeping up-to-date regarding the linking of AutoCad and Enterprise Dynamics software
- Research on possible efficiency improvements regarding reuse of work in phases after the sales phase
- Involvement in the development of the ED BAXSIM library

Two recommendations are made concerning research on the cost aspects of a BHS:

- Research on life cycle costs data to elaborate the cost calculator
- Research on extension of the design choices justification tool with financing aspects

Preface

In front of you lies a true milestone. This report not only constitutes the completion of my study of Systems Engineering, Policy Analysis and Management at the Delft University of Technology, but also the end of my life as a student. Ready for the next phase.

This report contains the findings during my master thesis at Vanderlande Industries B.V. Although I have used company related terminology, I have tried to keep the report accessible for interested people without any prior knowledge of baggage handling systems. For those who want to get an idea of the performed research and the outcomes at a glance, an executive summary is included at the beginning of the report.

Because I have aimed my research mainly on matters that could be improved in the current situation at Vanderlande, this report might give the reader the idea that a lot of things are badly organised within the Vanderlande organisation. Hereby I want to emphasise that there are also a lot of things going very well, something what is underlined by the confidence in the Vanderlande by many regular customers.

While going through each phase of the course that led to this report, I have been supported by several people. I want to thank these people for their time, knowledge and/or moral support they invested in me and my project. To start with, I would like to thank Ton van Wieringen and Edwin Valentin for being a member of the examination board. During the entire project they have supplied me with annotations on intermediary products and guiding comments. I also want to thank the other two members of the examination board, Professor Sol and Marcel Ludema, for the required critical notes on interim reports.

Furthermore, I would like to thank all employees of Vanderlande Industries that were involved in my project in some way and especially my “colleagues” of the simulation department. They were always available for help and they not only formed my oracle, but also gave me an enjoyable time at Vanderlande. Finally, last but not least, I thank family and friends, and especially my girlfriend Susie, for their continuous support during both good and rainy days.

Veghel, June 2002

Tjipke Lemain

Glossary

BHS	Baggage Handling System
BHS concept	A description of a BHS, consisting of documentation of the applied equipment types, the system layout (a line diagram) and often a rough controls description
BHS design	The composition, analysis and evaluation of BHS concepts
CAD	Computer Aided Design
Call for tender	The document (hard copy or digital), written on the authority of the customer's organisation, which is sent to the potential BHS suppliers and contains the requirements on the BHS (sometimes detailed to layout level) and peripheral conditions which the suppliers have to meet in order to be in the race for the contract awarding
CapEx	Capital Expenditures, the purchase price of a completely installed BHS
CC	Customer Centre
Concepting	The composition activity of BHS concepts
COO	Cost of Ownership
CRM	Customer Relation Management
Customer	Artificial persons in private or public law with the funds to pay for the BHS project and its end product. Although a party becomes an actual customer the moment a delivery contract is signed, the term customer in this report is used for both the potential and actual customer
EBS	Early Baggage Storage
HBS	Hold Baggage Screening
IDEF-0	Integrated computer aided manufacturing definition language
LCC	Life Cycle Cost
Line diagram	A schematic representation of a BHS, containing the processes and their connections/sequence
MFD	Material Flow Diagram
PFD	Process Flow Diagram
PRF	Proposal Request Form
Sales engineer	Employee of a Customer Centre of Vanderlande Industries, responsible for the composition of the tender document made for the customer, including the actual BHS design
SE	Systems Engineering
STD	Standard Time of Departure
Systems engineer	Employee of the Systems Group (Staff department) of Vanderlande Industries, among other things able to support a sales engineer in the BHS design
Tender document	The document (hard copy or digital), written on the authority of Vanderlande Industries, which is sent to the potential customer containing a complete description (layout, technology/controls description, CAD drawing, simulation report, price and terms of delivery) of the proposed BHS
VI	Vanderlande Industries B.V.

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1 Introduction

When people take a flight, for instance for holidays, they deliver their baggage at a check-in desk at the airport. From there on, the Baggage Handling Systems (BHS) of two or more airports take care of the baggage to make sure it ends up at the right destination. One of the activities of Vanderlande Industries, on behalf of who this project is performed, is to design, manufacture and install such Baggage Handling Systems on airports. The desire of Vanderlande Industries to enlarge her market share by improving the current BHS design process formed the lead in this thesis.

This chapter introduces the company Vanderlande Industries (section 1.1) and the main characteristics of a Baggage Handling System (section 1.2). To guide the reader through the report, section 1.3 contains the report structure including reference instructions to increase the readability.

1.1 Vanderlande Industries B.V.

Vanderlande Industries B.V. is an international company that provides, among other things, automated material handling systems. The company's head office is based in Veghel, The Netherlands. It incorporates design, engineering, test and production facilities. In addition to the head office subsidiaries, so-called Customer Centres, can be found Europe, Asia, Africa and the United States of America. In 2001 Vanderlande Industries B.V. realised a net income of 16,0 million euro on a net sales of 452.2 million euro. This result was reached with 920 employees in total [Public Library, docnr. CP01-06].

The clients of Vanderlande Industries can be found in the areas Warehousing and Distribution, Baggage Handling Systems (BHS), Express Services Industry and Manufacturing Industry. This master thesis project is executed on authority of the Systems Group, which provides technical and commercial support to Customer Centres and Operations in developing system solutions for customers. The Systems Group consists of four sub-departments:

- Systems Development
- Simulation
- Proposal Verification & Pricing
- Knowledge Management

For more detailed information about the organisation is referred to appendix A, which also includes the organisation chart.

1.2 Baggage Handling System (BHS)

Because of the central role of the Baggage Handling System (BHS) in this thesis, this section briefly describes its definition (subsection 1.2.1), its possible baggage flows (1.2.2), the main processes that take place (1.2.3) and the components of a BHS (1.2.4).

1.2.1 BHS definition

To determine the definition of a BHS, first of all a definition of a system is given. According to Alter [Alter, 1996] a system is defined as;
A set of interacting components that operate together to accomplish a purpose. The components of the system can be organisations, people, machines, software and other systems.

Applying this definition to a BHS, the following definition, including the function, can be defined:
A baggage handling system is a set of interacting transport, sort, process, store and control components and operators that collaborate in order to control and handle all baggage flows on the airport. Controlling and handling takes place from the baggage acceptance locations to the aircraft stands and from the aircraft stands to the baggage delivery to the passenger. In case of transfer baggage, from one aircraft to the other, it provides the control and handling between the aircraft stands.

According to Vanderlande Industries [Bartelet et al, 2000] the scope of a baggage handling system can be defined as follows:
All equipment and personnel that is necessary to handle all baggage (excluding hand luggage) between the locations of check-in, re-claim and the aircrafts and if required to ensure that all the appropriate bags entering the aircraft are security screened and reconciled with passengers. Besides that the BHS ensures effective data collection, transmission, storage and analysis in order to optimise the system performance.

In this thesis, the scope of a BHS is demarcated to the baggage handling inside the airport terminal building only. Transport between the terminal building and the aircraft stand is not integrated because Vanderlande Industries does not supply equipment for this part of the baggage handling. Terms used in these previous definitions are clarified in the two following subsections.

1.2.2 Baggage flows

In order to illustrate the possible baggage flows in a BHS figure 1.1 is included. The baggage flow entering the system at landside (area of the terminal building to which the public has access to) at the check-in desks is called the originating flow. This flow is transported to the airside, to the area (build or make-up) where the baggage is stacked at containers (or carts). These containers are transported directly to the departing aircraft.

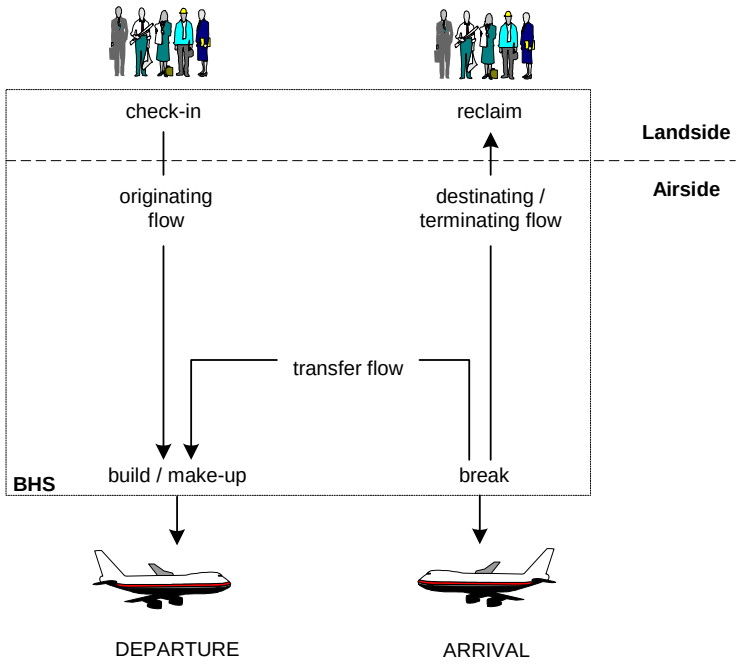


Figure 1.1 Baggage flows in the BHS.

In the opposite direction, the containers arriving by aircraft are transported to the terminal building and unloaded and sorted at the break area. A part of the baggage flow goes to the reclaim area to be collected by the passengers. This is called the destinating or terminating flow. The other part of the baggage arriving at the break area goes to the build area to be stacked on containers again, the transfer flow. The mix of terminating and transfer flow depends on the type of the airport (hub or final destination/feeder).

1.2.3 BHS processes

Figure 1.2 illustrates the most common configuration of the main BHS processes. Following the originating flow, the first process after check-in is the merger of all bags from the different check-in desks. Depending on the airport safety philosophy, the departing baggage is then screened (HBS, hold baggage screening) in order to prevent explosives entering the aircraft. Hold baggage is the baggage that will be stacked in the cargo hold of the aircraft. The next process is sorting the bags in order to make a distinction between “early baggage” and other baggage. Early baggage consists of bags that enter the BHS a long time (e.g. more than 2 hours) before the departure of the concerning aircraft. To handle this early baggage an Early Baggage Storage (EBS) is added to the BHS. This storage makes it possible to pick baggage out of the main baggage flows and store it for a certain time, depending on the time remaining till the STD (Scheduled Time of Departure) of the aircraft. That way the early baggage will not block the transportation lanes of the BHS and less flight make-up positions are necessary. The bags that don not have to go to or exit the EBS, follow their way on the main flow to the build area, where they are sorted again into different containers, depending on flight numbers, classes and destinations (the outbound flows).

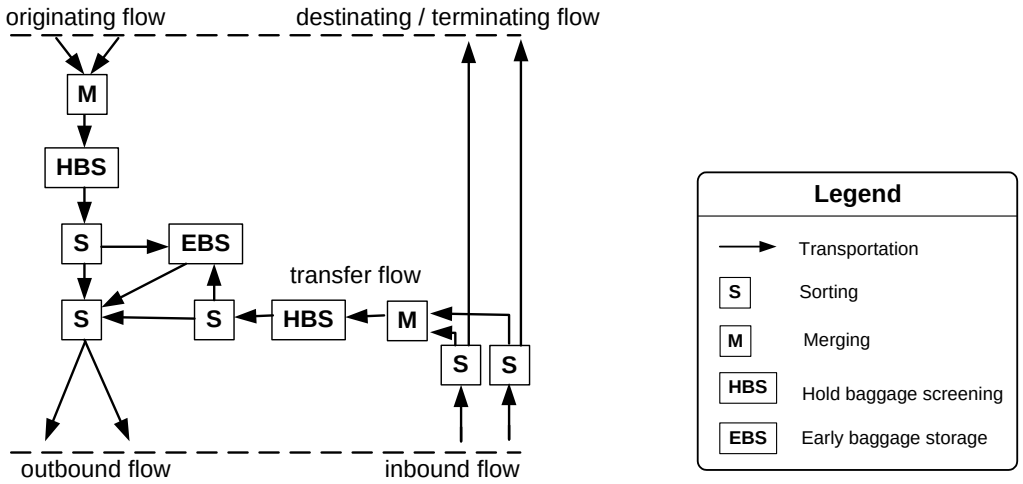


Figure 1.2 Basic processes and sequence in the BHS.

Following the inbound flow, meaning the bags arriving by aircraft and brought into the terminal building, the first process the bags undergo is sorting at the break area. Here the transfer flows are separated from the terminating flows. The terminating bags are sent to the reclaim carousels where the departing passengers pickup their bag. The transfer flows are merged to one flow and then, depending on the airport safety philosophy, screened by X-ray machines to detect explosives. After screening the bags are sorted again. In case there is a period of several hours between the two transfer flights of a bag, it is taken out of the main flow and sent to the EBS. Otherwise the bag goes directly to the build area and is sorted into the different containers.

Besides the processes as mentioned in the figure above, there are other processes that can appear in the BHS of airports. Scanning for instance, is done at several places in the system (depending on the size of the system and the level of automation) in order to identify the bags going through the system. This identification can among other things be used to link security screening results to bags or to track and route the bag through the system.

Reconciliation is another process that takes place at the moment the bags are put into containers in the build area. Reconciliation is the linking of a bag loaded and the passenger boarded for a particular flight. It is getting more and more usual that all departing baggage is to be reconciled with departing passengers. The loading information of the baggage, including the container, can be recorded. This way, the airline checks whether the right bags travel with the right passengers and detects suspicious situations, in case the passenger of a loaded bag does not show up.

In the different processes the BHS interacts with its environment. Besides handling the bags, the system communicates with several high level information systems and interacts with not only the passenger, but also the scan, screen and check-in operators, the

maintenance and loading operators. See appendix B for more details of the interaction between the BHS and its environment.

1.2.4 BHS components

In this subsection the common components that are applied in a BHS are briefly described, divided in check-in, transport, sorting, merging, build, storage, security screening and scanning and control components.

Check-in components

The check-in components consist of a desk including the integrated conveyor belts. The main functions carried out at the check-in desk are data entering, weighing, labelling and inducting the baggage. The desk operator carries out the first function. The last three functions can be carried out by the belts.

Transport components

The transportation of the bags between the different areas of a BHS is supported by transport equipment. Vanderlande Industries developed the following transport equipment for baggage handling (see figure 1.3):

- Conveyors with loose baggage
- TUBTRAX® , tubs, which can be placed on conveyors
- BAGTRAX® , carts (tubs with wheels) that can be placed on rails, high speed transport
- COMBITRAX® , which is the same as BAGTRAX®, but the tub can be separated from the carrier.

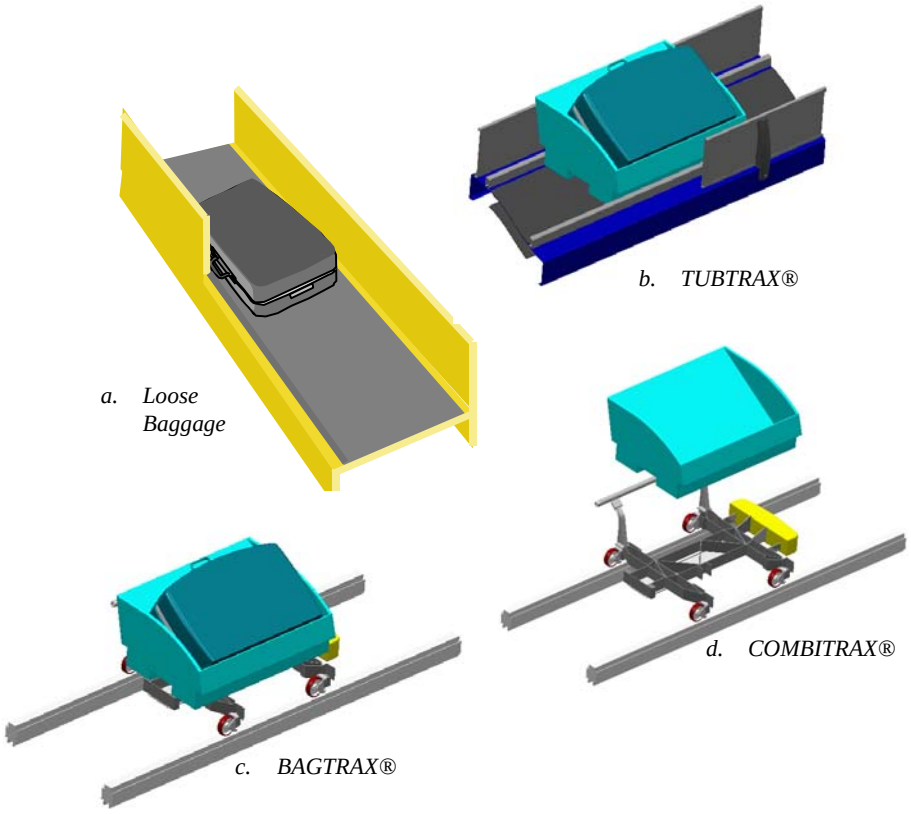


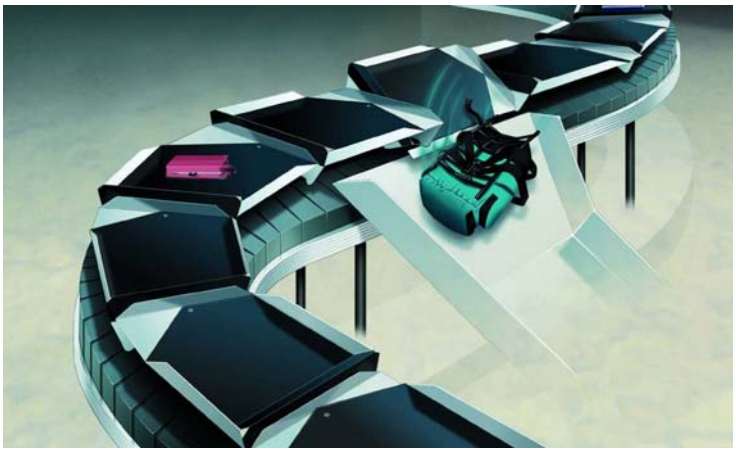
Figure 1.3 The transport equipment of Vanderlande Industries.

Sorting components

In order one baggage flow into two or more flows, sorting components are added to a BHS. Three examples of important sorting components are the TRIPLANAR®, the HELIXORTER®, and the VERTISORTER®.

Sorting by a TRIPLANAR® is a way of manual sorting. A TRIPLANAR® is a round carousel conveyor from which the operators can pick baggage with a certain destination label (see figure 1.4).

Figure 1.4 A TRIPLANAR® for manual sorting.



A HELIXORTER® exists of a loop with extended trays (see figure 1.5). A baggage item can be dropped off at a certain point by tilting the concerning tray. It can handle a lot of destinations and, depending on the configuration of the chutes (exit points), it has a high capacity.

Figure 1.5 A HELIXORTER® for automated sorting.

Figure 1.6 shows a schematic picture of a VERTISORTER®. It has two positions: up (black conveyors) and down (red conveyors). The blue conveyors are not part of the VERTISORTER®. The baggage item arrives on the blue conveyor on the left. If it has to go to the upper conveyor on the right, the VERTISORTER® will be in the black position. If it has to go to the lower conveyor on the right, the VERTISORTER® will be in the red position. Notice that in this case the upper red conveyor is lifted so large baggage items can also go to the lower conveyor.

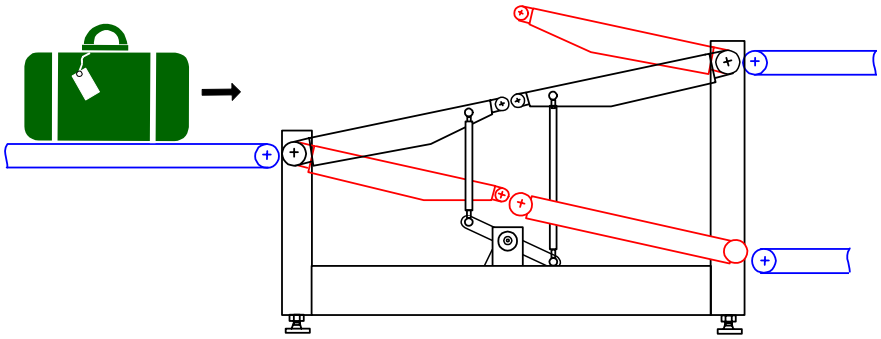


Figure 1.6 Schematic illustration of the VERTISORTER® (side-view) for automated sorting.

Merging components

A merge component is a reversed way of sorting, from two directions to one direction. Most common is the side merge, where a conveyor ends at the side of another conveyor (or sorter, in that case the merge is called a induct). By using the VERTISORTER® of figure 1.6 in the opposite direction, it can also be used as a merge component. In that case it is called a Vertimerge.

Build components

At the build area (or make-up area) the baggage is taken off the BHS and stacked in carts (or containers) for transport to the aircraft. Therefor the bags are collected in a way the

operators can easily grab them and put them into the cart. The bags can be collected on a TRIPLANAR® as described above. Other components are the lateral and the bin. In case of a lateral the bags is put on a straight conveyor belt that accumulates the bags. It is possible for the operators who work at the conveyor belt to activate the belt in both directions automatically to grab the bag and put them in the right container

In case of a bin the bags are dropped and slide down to the end of the bin and stay there until the operator puts them into the concerning cart (see figure 1.7). It is hard to put more than one cart around a bin, so in principle no manual sorting will take place.

Figure 1.7 Several bins with a baggage cart in front of them.

Storage components

According to Vanderlande Industries [Bartelet, et al, 2000] early baggage can be defined as the bags that are introduced in the system for which the destination bin, lateral or TRIPLANAR® is not yet open. As mentioned in sub-section 1.2.3, these bags can be stored in an Early Baggage Storage (EBS) for a certain period of time. In general one of the following 4 EBS alternatives is applied:

- Manual storage and retrieval
- Automatic dynamic storage
- Automatic storage in lanes (loose baggage, totes or carts)
- Automatic storage and retrieval system with cranes

In case of a manual storage and retrieval EBS, the bags are taken out of and replaced in the main flow by operators. They are stored in containers or racks. The automatic dynamic EBS consists of a conveyor loop in which the baggage is continuously circulating. The bags enter and leave the EBS by VERTISORTER® 's. In case of automatic lane storage (see figure 1.8), each conveyor lane contains bags with a STD within a certain period of time. So the lanes are emptied one after the other with e.g. an interval of half an hour. In the left lanes configuration a recirculation lane is integrated in order to recirculate baggage from a storage lane from which one (or several) item has to be released onto the sorter (for instance because of a change in the corresponding flight). In the right configuration the sortation to the different lanes is done directly from the sorter and in case of recirculation the sorter itself is used.

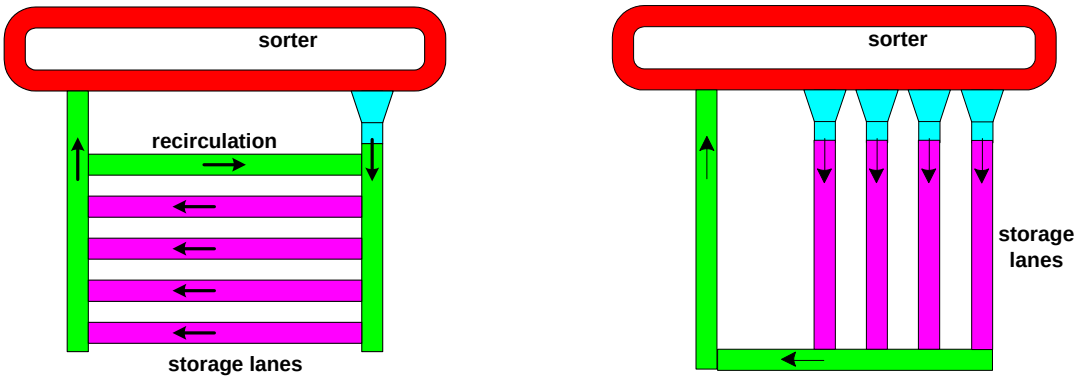


Figure 1.8 Two configurations for EBS in lanes.

Storage of baggage in high racks by means of several cranes offers more flexibility because of the possibility of random retrieval. Such a configuration of EBS is mainly used in BHS with high volumes that requires thousands of bag positions.

Security screening and scanning components

Security screening and identification equipment is not build by VI. Usually sub-contractors supply these components. Security screening (usually referred to as Hold Baggage Screening, HBS, because it concerns bags loaded in the plane's cargo hold) is applied to detect explosives and can exist of several levels, namely:

Level 1: Automated check by a smart X-ray device
Level 2: An operator analysis the X-ray reproduction
Level 3: Automated check by a CT machine
Level 4: An operator searches by hand (with the passenger present)
Level 5: The bag is destroyed

Scanning (identifying) the baggage label is done manually by handheld scanner or automatically by an infrared scan device above a conveyor belt (both reading a bar code).

Control components

In order to control the baggage flows there are three control systems integrated in a BHS, namely:

- Baggage Destination System (BDS)
- Baggage Routing System (BRS)
- Programmable Logic Control (PLC)

The BDS receives the flight schedule and chute allocation from an external information system (see figure 1.9). It also receives the Baggage Source Messages (BSM) and Baggage Transfer Messages (BTM) from a world wide information system (see appendix B for further details about interfaces with a BHS). These messages contain information of the bag (a unique License Plate, a passenger name, a flight number, etc.). Based on this information the BDS is able to link a destination code to a License Plate of a bag. So when the BRS sends a License Plate, the BDS returns the destination code for the

concerning bag. Based on this code, configuration and status of the equipment, the BRS determines the routing of the bag through the system. This route is sent to PLC level that is the lowest level of control. It controls the equipment of the BHS (in other words, it starts and stops a conveyor, sets a sorter in a certain position, etc.). In order to do this, the scanning and tracking equipment sends the ID information of the concerning bag and its speed and location.

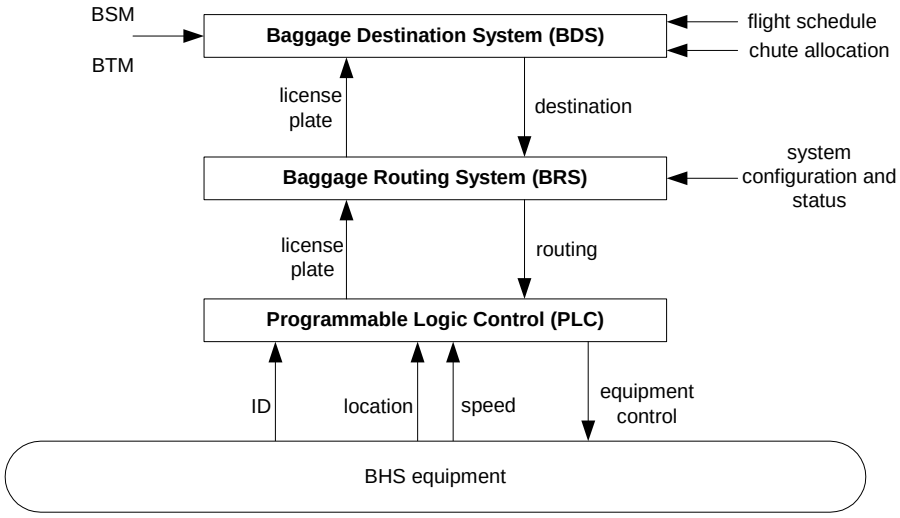


Figure 1.9 Three levels of control systems in a BHS.

For more detail on interfaces with the BHS (controls), e.g. by the Management Information System (MIS), is referred to appendix B.

1.3 Report structure

After this introduction, chapter 2 starts with the description of the research approach. Chapter 3 maps the current situation in the BHS design process. Based on this "as-is" description, the problems are analysed in chapter 4. Chapter 5 deals with these problems, by suggesting a new design methodology, based on solutions as revealed during interviews and studying literature. To support the employees of Vanderlande Industries in the new design methodology, tools are introduced, as described in chapter 6. The total package of methodology and supporting tools is evaluated in chapter 7. In chapter 8 a suggested implementation plan is described, to implement the new methodology in the Vanderlande Industries organisation. Finally, conclusions are drawn in chapter 9, including recommendations for further research.

At the beginning of the report a glossary is included to clarify used terminology and abbreviations. In the text is referred to literature and electronic data on the Internet. These references are enclosed in [square brackets]. Right after chapter 9 a references overview is included. Finally there are appendices included with alphabetical index. They can be helpful in clarifying parts of the report and are referred to in the text.

2 Research description

This chapter deals with the reason why Vanderlande Industries needed the research as described in this master thesis and with the research approach. The first section, 2.1, describes the initial problem as stated by Vanderlande Industries at the beginning of the project. Section 2.2 contains the research objective, based on the initial problems. Then the research scope is demarcated to get research proportions that can be handled in the research time available (section 2.3) and finally the research approach is presented in section 2.4.

2.1 Initial problem description

When a new airport is built, or an existing airport decides to replace or extend their Baggage Handling System, usually a call for a tender is sent to potential suppliers, containing the requirements which the new (part of the) system should meet. When Vanderlande Industries decides to tender for the concerning project an engineer designs a BHS, based on the information in the call for tender and his experience. The system design lays the foundation of the tender document that is sent to the customer. This tender document forms the basis on which the customer decides whether to award the contract to Vanderlande Industries or to a competitor.

In the phase of evaluation of all the received tenders, the customer makes several considerations and chooses a system supplier. Vanderlande Industries suspects that an improvement in the tuning of the offered BHS to the considerations of the customer is possible. Besides, the BHS design choices, made during the system development, depend on the engineer who designed it and are often not documented (and unclear to colleagues). Vanderlande Industries therefor beliefs that the development of a BHS is subjective and depends too much on the (lack of) experience of the engineer.

Concluding the previous, the following problem description, divided in two sub problems, was defined for this master thesis project:

1) ***At Vanderlande Industries lives the notion that the Baggage Handling Systems offered in the tender documents can be tuned in a better way to the requirements and wishes of the customer and the system's environment.***
2) ***The foundation of the choices made during the design of a Baggage Handling System is often unclear and depends too much on the engineer who is involved.***

2.2 Research objective

Based on the problems as mentioned above, the following project objective is defined:

Creating a situation at Vanderlande Industries in which engineers design Baggage Handling System solutions, based on clear justification of design choices which are well tuned to the total set of requirements and wishes of all stakeholders.

2.3 Research scope demarcation

The main initial constraints on the project were given by the period within which the project had to be performed and the subject scope that had to be within the scope of the study Technology, Policy and Management. Further demarcation to the solution space was necessary in order to reduce the complexity of the problems and to create controllability of the project. The following initial demarcations applied.

Baggage Handling System

Although Vanderlande Industries supplies more material handling systems besides the BHS, such as Express Parcel Systems, only the BHS is taken in consideration in this thesis. Besides, only BHS for mid-range airport terminals are included (mid-range terminals deal with 2 up to 15 million passengers a year).

Sales phase

This thesis focuses on the sales phase. This is the phase from the first "trigger" that starts Vanderlande Industries spending time on developing a BHS for a potential customer until the moment the customer signs the contract (or refuses the proposed BHS). So the sales phase is the quotation phase.

Concepting

This thesis focuses on the concepting part of the BHS design. A concept of a BHS exists of the description of a BHS by the documentation of the equipment, the system layout and often the description of the rough controls of the system. The concepting activity is performed by a Sales or Systems engineer (see section 3.1 for further detail).

Vanderlande Industries's capabilities

The proposed solutions shall be in accordance with the current, or realistic future capabilities of the organisation of Vanderlande Industries and her employees.

Development time available for a BHS

The proposed, new way of working shall be in accordance with the time that is available for BHS design in the current and near future.

Customer requirements

Although the customer (and his requirements and wishes) plays an important role in this thesis, the potential customers are not approached themselves. Information about market demands is therefor mainly obtained by interviewing employees of Vanderlande Industries and reading internal documentation [Sales Reference Database].

Implementation

The actual implementation of the solutions as introduced in this report, is not included in the thesis project to keep the scope of the project in accordance with the time available. A brief implementation plan is included in chapter 8.

2.4 Research approach

The research activities are shown in the rectangles in figure 2.1, which represents their rough sequence. In reality there were many iterations because of the participating approach of the research (involved employees are listed in appendix C). Next to the activities, the products of the activities are shown, including the reference to the chapter of this report in which they are described.

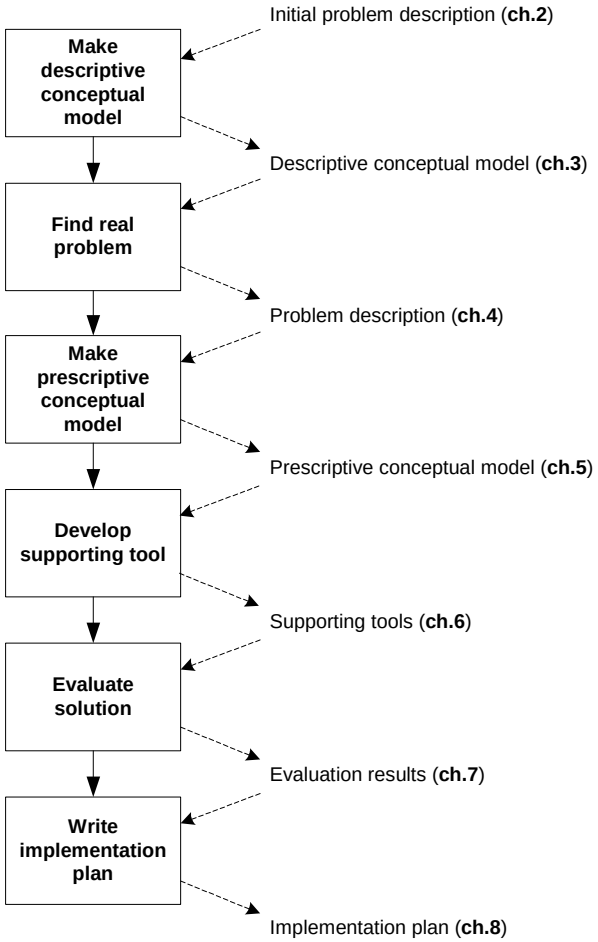


Figure 2.1 Research activities and products.

Make descriptive conceptual model

The project started with talking to the employees who were interested in the problem and especially its solution, and getting acquainted with the "world of baggage handling systems" by reading internal documentation, professional literature and visiting the Internet. This way the problem was explored (creation of a mental model). After the initial problems and objective were documented, the mental model of the current situation (the "as-is" situation) was translated in a physical descriptive model, in order to verify the current processes and requirements. The descriptive model made it is easier to understand and communicate (verify) the current situation. Besides that, the model of the current situation made it possible to discover problems or aspects of improvement. To describe the current situation, the work-centred-analysis framework is used [Alter, 1996]. This framework contains the following elements: Customers, Products, Business process, Participants, Information and Technology. These elements are described in chapter 3. To support the textual description of the element Business process, an activity-actor diagram was made. This diagram shows who (which "actor") performs which activity at what moment in the sales phase, including the global sequence of the tasks. To increase the insight in the process activities the IDEF-0 method (Integrated computer aided manufacturing DEFinition language) is used to model the current design process. This method is derived from SADT (Structured Analysis and Design Techniques) and divides a process activity in several sub-processes and activities. It makes it possible to zoom in at these sub-processes as much as necessary to look at them in more detail. A more detailed model explanation can be found in appendix D1.

Main elements in this phase of the thesis project were communication, modelling and iterations.

Find real problem

The first activity of the problem analysis was verification of the existence of the initial problem, as stated by the Systems Group of Vanderlande Industries. The confirmation was only qualitatively found, while interviewing employees of different departments of Vanderlande Industries (see appendix C). Quantitative confirmation could not be found. To find the real underlying problems, the implications of introducing the desired situation at Vanderlande Industries were mapped. Based on these implications, an analysis of the descriptive models of the current situation and interviews with the different employees lead to redefinition of the problems. For these problems the question "Why is it a problem?" was answered to communicate (and therefor verify) the problems and to show the necessity of solving these problems.

Make prescriptive conceptual model

The search for possible solutions was mainly based on information gathered when talking to the involved engineers, literature studies, exchanging thoughts with suppliers of supporting tools, and discussions with employees of the Delft University of Technology. First, all information together formed the "to-be" situation in mind. Thoughts and ideas were communicated with stakeholders of the thesis project and their remarks were integrated this mental "to-be" model. Prescriptive conceptual models of the new "to-be"

business process were made and communicated in order to elicit feedback, maintain and create support for the solutions and support the evaluation activities. The models exist of an activity-actor diagram and an IDEF-0 model, both accompanied by textual description.

Develop supporting tool

In order to support the new business process activities, automated tools were introduced. First, the requirements for the new tools were defined by talking to the (future) users and reading literature concerning automated support. Then tools were developed or just evaluated in case of existing tools. More details on the tools can be found in chapter 6.

Evaluate solution

Because of the limited time during the thesis project the proposed solutions were not evaluated in a real situation. Instead, the prescriptive models of the new "to-be" situation were evaluated with Vanderlande Industries employees (see appendix C for the list of involved employees). The supporting tools were evaluated by confrontation with Vanderlande Industries employees and application in test cases. More details on the evaluation can be found in chapter 7.

Write implementation plan

To initiate the change from the current "as-is" situation to the proposed "to-be" situation, a brief implementation plan is included in this report. It advises Vanderlande Industries on how to realise the change to the new desired situation (chapter 8).

3 Current baggage handling system design process

Within Vanderlande Industries there are three phases that are distinguished during a total BHS project life, namely the sales, build and service phase (figure 3.1). This thesis focuses on the sales phase. Most of Vanderlande Industries' orders are handled as a turnkey project. The sales phase is carried out before the project is actually sold. A BHS is sold on the basis of a designed system concept, a price and a planning. A system concept exists not only of a functionality definition, but also includes the layout, the technology used for each part of the system and often the results of a simulation study.

When the system is sold, the build phase starts with elaborating the system concept design and manufacturing the equipment. After installation and extensive testing of the system to take care of possible start-up problems, the customer can use it for operation. In the service phase, a service team will take care of preventive maintenance and will be stand-by to solve occurring problems.

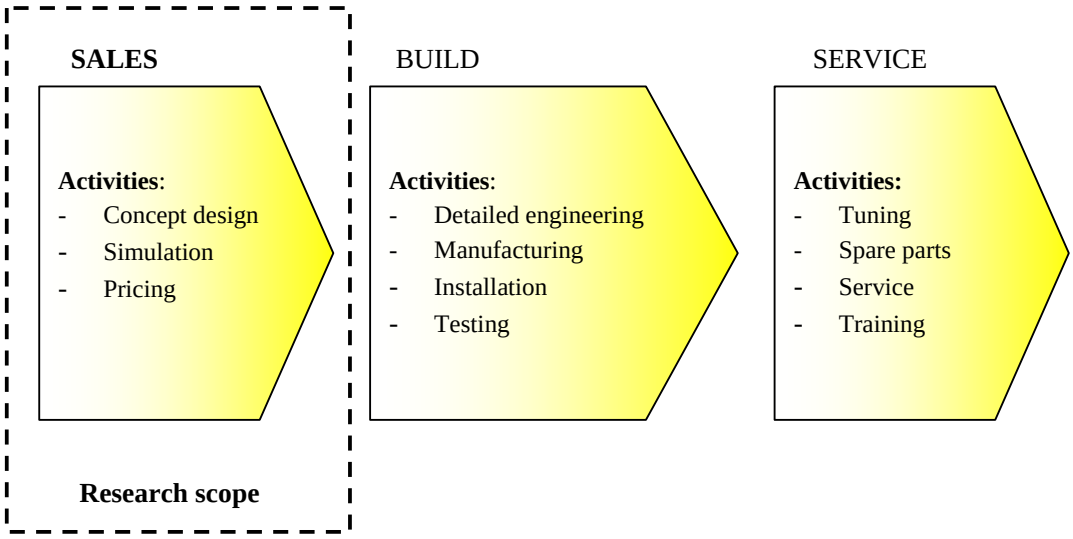


Figure 3.1 Project phases at Vanderlande Industries with the main activities.

If a new project is relatively small and simple, the Customer Centres take care of all three phases except for the manufacturing and simulation parts (see appendix A for additional details on Vanderlande Industries). When a project becomes more complex, the engineering parts of the sales phase are supported by the Systems Group in Veghel.

As mentioned in section 2.4 the work-centred-analysis framework is used to map the current situation in the sales phase. The elements of this framework, being the stakeholders, the business process, the products, the information and the technology, are discussed in the following sections, starting in 3.1 with the stakeholders, being a combination of the customer, Vanderlande Industries employees and other participants.

3.1 Stakeholders involved in the current BHS design process

In this thesis “the customer” is not only the stakeholder (person, group or organisation) in the sales phase that wants to buy a BHS, but also the stakeholders who are involved in the purchase on wish of the buyer. For instance, often the airport management calls in a consultancy firm in order to compose the requirements for the desired system or to evaluate the offered system solutions. This way, the consultants have a great influence on the final decision of the buyer which supplier to choose. So the term “customer” can include:

- Airport employees (on several levels such as management, operations and maintenance)
- Consultants (it has become usual that a consultancy firm is hired by the airport in order to support them during several steps in the purchase process, such as defining the future developments and formulate the system requirements)
- Airlines (mainly in the USA owners of the airport terminals)
- Handling agent (independent stakeholder with core business baggage handling, e.g. OGDEN)
- Third party: e.g. security stakeholder (independent stakeholder with core business guaranteeing security on the airport and/or in the aircrafts)

Other external stakeholders (no employees of Vanderlande Industries) can be of importance during the sales phase, such as:

- Competitors (also suppliers of (parts of) BHS)
- Business partners (e.g. a company who delivers the system controls)
- Sub-contractors (suppliers of intermediary products)
- Project managers (external project managers who are hired by the customer in order to lead the total project)
- Public authorities (on several levels, e.g. the EU prescribing purchase processes, the local government prescribing working conditions and authorities enforcing security legislation)
- Media (negative or positive news about e.g. Vanderlande Industries or a competitor can influence the decision of the customer)
- Commercial organisations with influence (for instance a important customer of the concerning airport)
- Agents (in several areas Vanderlande Industries works via agents who obtain a provision if a system is sold)
- Financiers (e.g. banks that buy the BHS and rent it to the airport)
- Architects (the architect(s) of the airport terminal building)
- Customs (security enforcement)

Note that a competitor can be a sub-contractor, a partner or even a main-contractor in another project. Besides the external stakeholders, there are several stakeholders to be distinguished within Vanderlande Industries who all contribute to the processes at Vanderlande Industries during the sales phase, such as:

- Vanderlande Industries higher management

- Area manager (managing several Sales men of a Customer Centre(CC))
- Sales engineering manager (managing several Sales engineers of a CC)
- Salesmen (direct contact with the customers, stationed in the CC)
- Sales engineers (developing concepts for customers of certain market area e.g. Germany or South Africa, composing the total tender document including pricing and terms and conditions, stationed in the CCs)
- Systems engineers (supporting the Sales Engineers in developing concepts, , stationed in Veghel)
- Simulation engineers (evaluating the dynamic behaviour of system concepts, mainly stationed in the German CC and in the Veghel-office)
- CAD engineers (drawing the BHS and terminals in AutoCAD)
- Controls engineers (developing the controls of the BHS)
- R&D engineers
- Mechanical engineers
- Calculation engineers (checking and making calculations of the BHS prices)
- Vanderlande Industries' project manager (managing the total project, mainly during the build phase)

For further clarification of the difference between a Sales engineer and a Systems engineer at Vanderlande Industries, figure 3.2 is included. The Sales engineer, working at a Customer Centre of Vanderlande Industries, is responsible for the total quotation made for the customer. The quotation is documented in a tender document. Of all activities a Sales engineer performs, the design of BHS concepts (concepting and evaluating) can be supported by a Systems engineer. The Systems engineers work within the Systems Group which operates as a Staff Department for all Customer Centres. In case a Sales engineer lacks the required experience for a BHS project, or lacks the time to handle the project, the System engineers can support by taking over the concepting part of the sales phase.

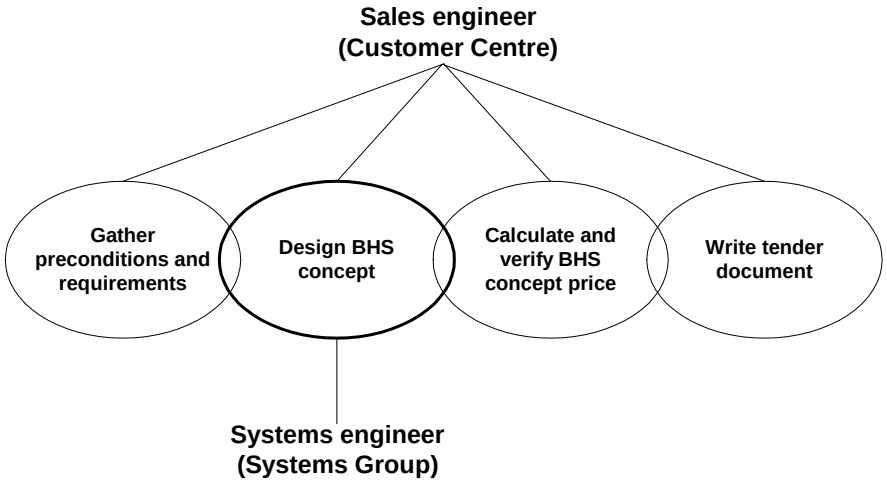


Figure 3.2 The main activities performed by the Sales and Systems engineers.

3.2 Products of the current BHS design process

In this subsection the outputs or results of the sales phase are specified which are used directly by customers of the BHS design process or the process participants. They are arranged chronologically by the moment they appear in the process. The IDEF-0 model of the current situation in appendix D1, as introduced in the previous section, also contains these products in relation to their process activity.

Proposal request form (PRF)

The first step of the Salesman when approached by a (potential) customer is gathering the most fundamental requirements (global functionality description). Based on these requirements the Salesman, the management of Vanderlande Industries and Engineers decide whether to tender or not. If Vanderlande Industries decides to tender, the Salesman writes a PRF to officially identify the project inside Vanderlande Industries and to put the engineers to work. Note that the customer often approaches several suppliers before they have written down their requirements and therefor the engineers of Vanderlande Industries often start working on a project before the official requirements are received.

Call for tender

The call for tender is a document made by the customer (or e.g. by a consultancy firm hired by the customer). The compositions of a call for tender differ enormously. In some projects there were only a couple of pages describing the main requirements of the system related to the performances. In other cases there were piles of requirements and constraints, completed with the required layout and performances of the future system and the contractual conditions. In most occurring projects, parts of the system layout (such as the location and number of check-in desks and the location of the make-up area) and the main performance requirements are defined.

Process Flow Diagram (PFD)

Based on the information gathered, the Sales engineer starts defining the configuration of the BHS. In order to make a line diagram, first two smaller steps are made, namely making a PFD (Process Flow Diagram) and a MFD (Material Flow Diagram). The PFD (see figure 3.3) shows what happens with the baggage. It deals with questions such as: does the baggage need to be screened, is there a storage, in what sequence are the several baggage handling processes connected, etc. In the PFD shown below the baggage brought in the system at the check-in desks is first read. If the label on the bag cannot be read, the bag goes to manual coding. Then, based on the security level for the different countries the bag can go to the Hold Baggage Screening level 1&2 and based on the results to Hold Baggage Screening level 3&4. If it concerns early baggage it will be stored in the Early Baggage Storage for a while before sorting it out to the destinations. The transfer baggage can follow the same flow, but can also skip the processes and go directly to the destinations.

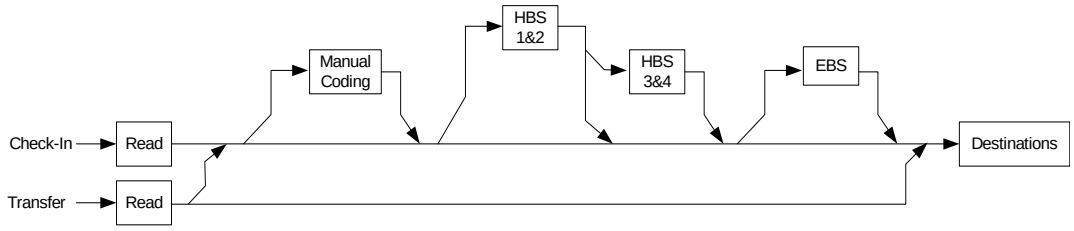


Figure 3.3 An example of a process flow diagram (VI internal drawing technique).

Material Flow Diagram (MFD)

The step from a PFD to a MFD is a small one. The MFD is similar to the PFD, but now the expected and calculated (peak) baggage flows between the processes are added. The peak flows are the highest (expected) baggage flows (number of bags per time unit) that can occur due to fluctuations in the offered bag volumes. Note that the MFD represents the peak flows that may occur at different times (not simultaneously) so the flows can not be added or subtracted without knowledge about their relation in time.

Line diagrams

Based on the PFD, MFD and choices of used technology the Sales engineer draws the system layout in a line diagram. Figure 3.4 shows a part of a BHS visualised by a line diagram. Together with a textual description, the line diagram forms the backbone of a BHS concept.

In a line diagram each line represents a transport line. The figure shows the screening and coding configuration from check-in and transfer baggage. The number of required transport lines and equipment are based on the expected peak flows and the capacity of the used technology. In this line diagram for instance, three manual coding stations are integrated to handle the total expected flow of “no-read” baggage.

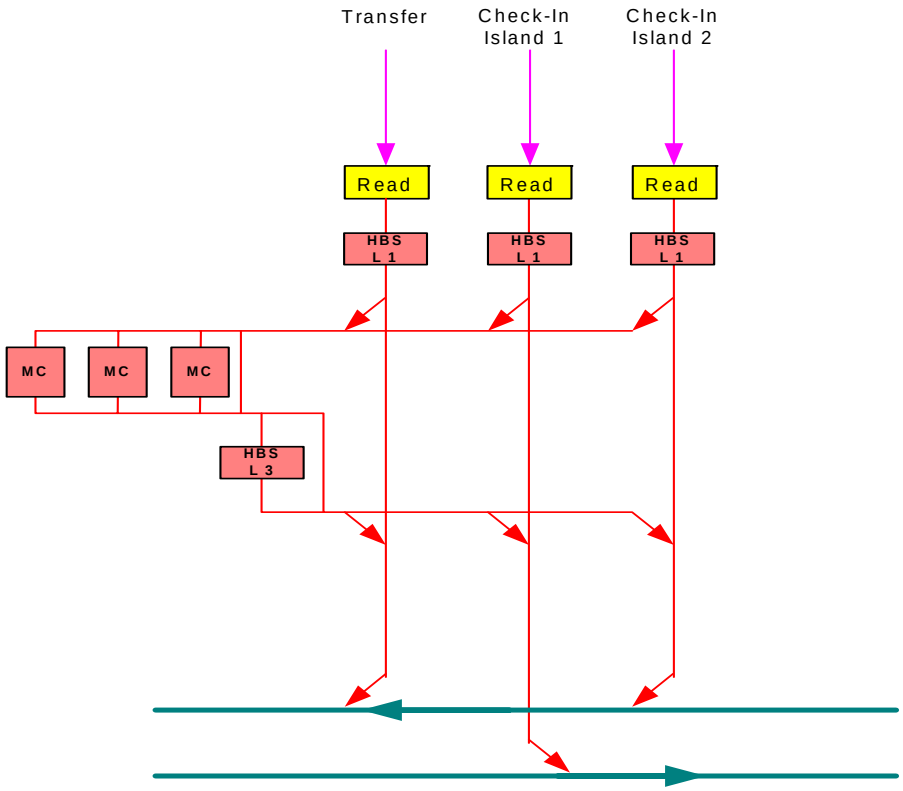


Figure 3.4 A Line Diagram of a baggage handling subsystem (VI internal drawing technique).

Tender document

The tender document is the official quotation that is given to the customer. Based on this document (mostly in combination with a presentation) the customer evaluates the Vanderlande Industries offer in comparison with the competitors. Based on this evaluation the choice is made which supplier will be awarded with the contract.

The following topics are discussed in a common tender document:

- Problem and solution description (including the bag dimensions, capacities, flow diagrams, building description, operational area and constructional circumstances)
- System functions (functioning of the offered system including advantages)
- Mechanical materials (general characteristics of the mechanical materials offered)
- Controls (describing the control configuration, including aspects as supply voltage, software, observations, interfaces, PLC control and product identification)
- Project management (planned activities and products)
- Installation (preconditions and size of delivery of the assemblies)
- Commissioning (including description of commissioning, acceptance criteria, first take over and final hand over)
- After sales service (recommended spare parts, service, training and documentation)
- Pricing (summary of the price calculations of the quotation)
- Terms and conditions (validity of the quotation, terms of payment, guarantee, etc.)

- Appendices (if applicable a planning, specifications of the resale equipment offered, layout drawings and results of a simulation study proving the BHS meets its requirements)

3.3 Description of the current BHS design process

The first subsection (3.3.1) of this description of the BHS design process deals with the overall process to clarify the interrelation of the actual concepting activities of the Sales and Systems engineers and the other activities in the sales phase. Subsection 3.3.2 deals with the activities of the Sales and Systems engineer in more detail.

3.3.1 Current overall BHS design process in the sales phase

The scope of this thesis project is demarcated to the sales phase of a BHS. In this sub-section a activity-actor diagram is included in order to place the concepting activity of the BHS in its context. The diagram shows the relations in time between the activities of the different disciplines at Vanderlande Industries. Besides, the main activities of the customer that directly influence the Vanderlande Industries activities are integrated. Note that the activities and sequence of the activities as described apply to most projects, but each project has its own variations.

The actors can be found in the upper row of figure 3.5 and all them have their own span of the sales phase (the columns). First actor is the customer. As mentioned in the section 3.1, the customer can exist of several parties. The Vanderlande Industries employees directly involved in the sales phase are divided in the Sales Men, the Sales or Systems engineers, the Controls engineers, the CAD engineers, the Simulation engineers and the Calculation engineers. The boxes contain the different primary activities, being the activities that are directly related to the BHS concept design process. The managerial activities of the management of Vanderlande Industries are not included.

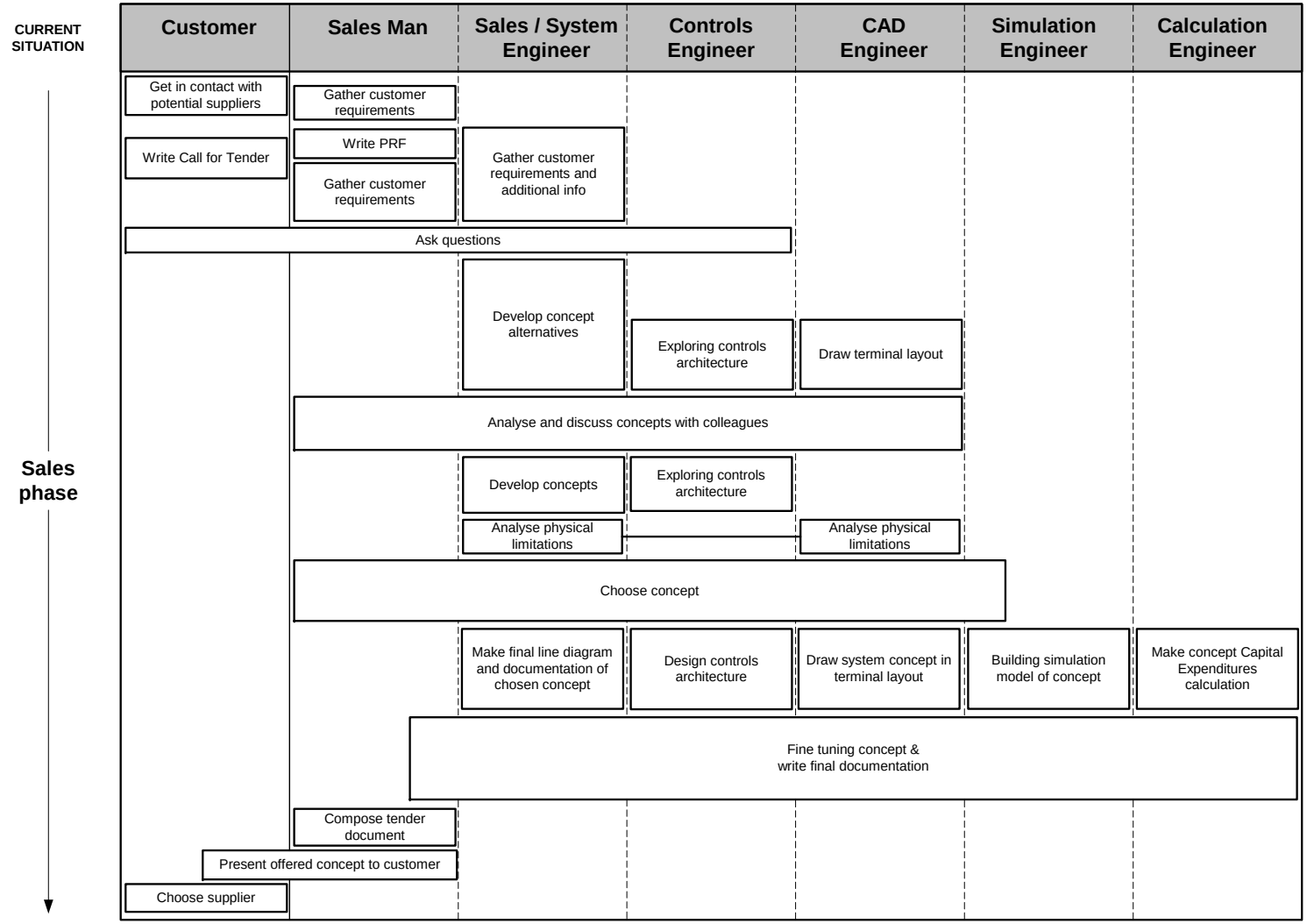


Figure 3.5 Activity-actor diagram of the current situation in the BHS concept design.

A sales phase at Vanderlande Industries starts at the moment Vanderlande Industries is contacted by the customer (in some cases Vanderlande Industries contacts the potential customers on there own initiative). The Salesman of the concerning Customer Centre starts gathering (and supplying) information from (and to) the customer in order to get an idea whether Vanderlande Industries could and should be the supplier for the requested system. If Vanderlande Industries wants to tender (put effort in offering a system for a certain price to the customer) the Salesman starts gathering information about the required characteristics of the system. The Salesman writes an internal document, the Proposal Request Form (PRF), with the main system requirements and sends it to a Sales engineer of the concerning Customer Centre. The PRF enables tracking and archiving the project activities under the same project number. The Sales engineer starts gathering information and requirements too and starts configure BHS concepts. In a meeting with the customer questions can be answered regarding the requirements as stated by the customer. When the experience of a Sales engineer in the BHS field is not sufficient to handle a complex project, a supporting Systems engineer of the Veghel office is requested to help configuring the BHS concept (see figure 3.2 of section 3.1).

The Sales engineer (or Systems engineer) makes several schematic diagrams of BHS concepts (see section 3.2). In the meanwhile the CAD engineer starts drawing the area of the terminal where the system has to be installed. During the creation of several options of BHS concepts the Sales engineer analyses and discusses the options and choices made with other colleagues, such as the Controls engineer. If remarks made convince the Sales engineer that the concepts have to be modified, he does so. Then one concept is chosen from the options and further detailed. Very important in this process is the feedback from the CAD engineer whether a concept configured in a schematic way, physically fits in the terminal area. Besides the schematic diagrams, the Sales engineer also describes the planned technology briefly. The CAD engineers draw the chosen BHS concept in the terminal building in order to convince the customer that the BHS will fit. The Simulation engineer builds a simulation model to confirm the performance of a BHS concept. First of all this confirmation preserves Vanderlande Industries from offering a BHS which can not meet the performance requirements. Besides, it convinces the customer that the presented concept will meet the performance requirements. If more complex controls are necessary, the Controls engineer is involved in the simulation model building too.

Now more than one engineer of Vanderlande Industries is working on the details of the concept, which in most cases results in several changes and adjustments (fine tuning of the concept). Finally, the Salesman gathers all the system descriptions and study results in a tender document and, if allowed by the customer, illustrates the offered system during a presentation. The sales phase ends at the moment the customer announces the supplier they awarded with the order.

3.3.2 Current BHS design process of the Sales and Systems engineer

This report focuses on the concepting activities of the Sales and Systems engineer. Therefor, IDEF-0 models are made in order to divide the activities in sub-activities and

zoom in for more detail. Appendix D1 contains these IDEF-0 models. They can support the understanding of the textual description of the design activities in this subsection.

When designing a BHS, a Sales and Systems engineer starts with gathering information. The first information is obtained from the Sales Man. During a conversation the engineer forms a mental model of the system to be designed. With this mental model in mind further information is gathered. In some cases e.g. the engineer uses the Internet when seeking for additional information (e.g. the current terminal buildings configuration or the airport authorities/ownership balance) or uses the Vanderlande Industries Public Library (local network) to find information about the Vanderlande Industries products and previous projects. While doing so the engineer often talks with colleagues to exchange knowledge. If the mental system model implies a certain technology that Vanderlande Industries does not manufacture and must be integrated in the BHS, potential sub-contractors are approached (for possibilities and prices). Normally the customer finishes the call for tender (see section 3.2) a couple of weeks after the start of the sales phase at Vanderlande Industries. The moment the call for tender arrives at Vanderlande Industries, the requirements as stated in the call for tender together with the other collected information form the system related requirements and peripheral information.

Once the engineer has an overview of the available information he/she has a conversation with the customer in order to elicit lacking information. Then, with all information in mind, the actual design starts. Based on the required functionality of the BHS the engineer draws possible Process Flow Diagrams, being the connections between and the sequence of the different functionalities. Then, after adding the (peak) material flows to the PFD(‘s) the engineer chooses the technology that should be used for each distinguished functionality. These choices start with the check-in and break technology, because often the customer requires certain technologies for these areas. After that, often in iterative steps, the technologies are chosen for the reclaim, build-up, EBS and HBS functionality. Finally the transport and sort technology is chosen. The combination of all mentioned technologies forms the BHS concept, drawn in a Line Diagram and accompanied with a describing text.

In several stages the engineer discusses concepts with colleagues and during these discussions choices are made which configuration of BHS technologies will be offered to the customer. The moment the concept is selected, the engineer elaborates the Line Diagram and the technology description that will be integrated in the tender document.

3.4 Information used in the BHS design process

In this section the information used in the sales phase is discussed. First, data, information and knowledge are distinguished according to the definition of Alter [Alter, 1996].

Data: Facts or images that may or may not be relevant or useful for a particular task.

Information: Data whose form and content are appropriate for a particular use.

Knowledge: Combination of instincts, ideas, rules and procedures that guide actions and decisions.

Data forms the base of information and knowledge is needed to extract the right information from the data and to use information effectively.

Data used in the sales phase
Besides general sources such as the newspaper, the engineers also use data obtained from more Vanderlande Industries specific activities such as searching on the Internet for project relevant information (such as terminal characteristics), reading specialist literature and talking to other engineers. It mainly concerns data like the market situation, customer information, competitor's products and (potential) subcontractor's products.

Information used in the sales phase
The guiding information source for the Vanderlande Industries engineers is the call for tender obtained from the customer. As mentioned before in the previous section the content of the call for tender documents vary (brief/extended performance/equipment specification). If the quantity of information is limited, the engineers have a lot of degrees of freedom in the BHS design. Sometimes the quantity of information is enormously and therefor becomes data to certain engineers. In that case the required information must be filtered out. The information that can be found in a call for tender often includes a problem description, the required functionality, the terms and conditions and drawings of terminal building (and sometimes a possible solution).

Vanderlande Industries engineers can review previous sold projects in the internal Vanderlande Industries Sales Reference Database. This database contains the main system characteristics (which technology and with what throughput capacity) and the selling price of earlier designed BHS. They also have access to the Vanderlande Industries Product Data Book that contains the technical specifications of all possible Vanderlande Industries components and most components of subcontractors. Finally they can consult the Airport Database that contains the main operational numbers of all airports in the world, such as the number of passengers per year, the number of terminals, the number of check-in desks, etc.

Knowledge used in the sales phase
Based on the Vanderlande Industries strategy the engineers apply their experience while taking actions and making decisions. They are supported by the Vanderlande Industries Public Library that is accessible from all workplaces and contains procedure guidelines. Besides, they can find design procedures and best practises concerning technology in the Vanderlande Industries System Books, composed by the Knowledge Management Team of the Systems group, supported by other departments.

3.5 Technology used in the BHS design process

This section describes briefly the most important technical tools that are currently used in the sales phase (see also the IDEF-0 models of the current situation in appendix D1). These applications are to be used on stand-alone or network computers.

MS Office including Visio
MS Word is the standard for reports. MS Excel is used for static calculations of capacities. MS Explorer is used to obtain information from the Internet. MS Visio, a graphical application, is used to draw PFD's and Line Diagrams.

CAD Tools
To proof the system will fit in the terminal building an AutoCad drawing is made. AutoCad is completed with "Villa", an application containing building blocks of BHS components to generate a bill of material)

AutoMod
To proof the BHS is compliant with the required performance the flow-oriented simulation package AutoMod is used by the Simulation engineers.

Pricing Tools
The Pricing engineers calculate the price of a system supported by three applications based on FileMaker Pro:

- CCP: Conveyor Calculation Program (equipment prices only)
- SCP: System Calculation Program (project related labour cost)
- PPS: Project Pricing Sheet (prices as charged to customer)

Lotus
Via the Lotus Notes Desktop application each workstation is connect to several communication and planning features. This application also offers the entrance to the Vanderlande Industries Public Library database, Vanderlande Industries Product Data Book and Vanderlande Industries Sales Reference Database.

4 Problem analysis

Finding the right solution to the right problem is impossible without a clear idea of the problem, the context and the solution direction [Sol, 2000b]. Therefor, the initial problems as stated in section 2.1 are verified in the first section of this chapter. Section 4.2 describes the implications of the new situation if the desired objective of section 2.2 has to be reached. With these notions in mind two questions were answered to clarify the real problems "behind" the initial problems. These questions are "What is the problem?" (section 4.3) and "Why is it a problem?" (section 4.4). Section 4.5 describes the solution direction and framework for the solution. The findings of this problem analysis are summarised in section 4.6.

4.1 Initial problem verification

The first initial problem as stated by the Systems Group reads as follows:

"At Vanderlande Industries lives the notion that the Baggage Handling Systems offered in the tender documents can be tuned in a better way to the requirements and wishes of the customer and the system's environment"

Vanderlande Industries has a good reputation regarding the quality of delivered BHS. Now Vanderlande Industries wants to enlarge her market share in the field of baggage handling but with competitors getting closer, Vanderlande Industries is compelled to reconsider the current way of designing and offering BHS to potential customers. In consultation with Vanderlande Industries the (potential) customers of the BHS are not involved in the verification of the first initial problem. A fulfilling market research would take too much time in relation to the thesis project time and the change to arrange an interview with the decision makers about BHS purchase in the customer's organisation would be small. Therefor, the information about market demands is mainly obtained by interviewing employees of Vanderlande Industries and reading internal documentation [Sales Reference Database].

Vanderlande Industries did not win all contracts for the projects the company made a quotation for. So, you can say that the fit between system and requirements as stated in the problem can be "better". But is that not always the case? Is it not so that things can always go better? Yes, but interviewing employees of different departments (see appendix C) revealed a (recognised) air of superiority at Vanderlande Industries when cooperating with external organisations. In former projects BHS layouts, designed and proposed by the customer, were put aside in the sales phase and Vanderlande Industries designed another, "better"(in the eyes of the engineers) solution for the customer's problem. Projects were also lost because the BHS was tuned to the requirements of the wrong, non-decision-making people of the customer's organisation. In conclusion, the

first problem as stated is recognised by the interviewed employees of Vanderlande Industries.

The second initial problem as stated by the Systems Group reads as follows:

"The foundation of the choices made during the design of a Baggage Handling System is often unclear and depend too much on the engineer who is involved"

To verify this problem the documentation of former projects was examined [VI_Projects, Sales Reference Database]. It appeared that these templates were only filled partly and that they contained a non-detailed description of the offered systems by describing the main applied system components (such as sorter and transport type and the number of check-in desks) only. The starting conditions of the BHS projects and the foundation of the choices made during the design were not documented. So, this confirms the existence of the first part of the problem. The second part of the problem, choices depending on the concerning engineer, could not be verified because of the lack of documentation.

Interviewing employees of Vanderlande Industries revealed that they endorse that the design choices are founded subjectively and without documentation. The employees explain the inadequate filled templates by the lack of objective of the documentation. They do not want to "document in order to document, without further reason ".

In conclusion, also the second problem is recognised by the employees of Vanderlande Industries.

4.2 Implications of the desired situation

The objective, based on the initial and recognised problems as stated in section 2.2 reads as follows:

"Creating a situation at Vanderlande Industries in which engineers design Baggage Handling System solutions, based on clear justification of design choices which are well tuned to the total set of requirements and wishes of all stakeholders"

The implications of such a situation are described regarding three aspects: the total set of requirements and wishes, the design choices and the good fit between them.

Total set of requirements and wishes

The concerned engineers have to be acquainted with the total set of requirements and wishes, by:

- Identification of potential stakeholders (persons or (sub-)organisations who can introduce requirements and/or wishes)
- Identification of the requirements and wishes of those stakeholders
- Prioritation of those requirements and wishes

Design choices

The concerning engineers have to record the design choices they make, including the justification for those choices. Clear justification implies unambiguous, if possible quantified justification.

Good fit

A good fit means the BHS is saleable (the customer prefers a contract with Vanderlande Industries to a contract with a competitor) and achievable for Vanderlande Industries from business economics, knowledge and capacity point of view. There are two ways to achieve a good fit: the design choices are based on the total requirements set or the total requirements set must be based on the design choices.

With these notions in mind, the current situation is analysed to find the underlying problems of the initial problems.

4.3 What is the underlying problem?

A closer look at the current situation, as described in chapter 3, is taken to determine the underlying problems regarding the total set of requirements and wishes, the design choices and the good fit (as stated in the previous section).

Total set of requirements and wishes

Interviews with employees revealed that the employees who are involved in the design process of a BHS (see section 3.1) often not exactly know who the real decision maker(s) is(are) in the customer's organisation. Besides, the arguments used by the decision makers to decide which supplier will be awarded with a contract, are often unknown. Several employees stressed that often the roles of other stakeholders in the decision process of the customer (the process in which the customer decides which BHS supplier will be awarded with the contract) were crucial to the decision that was made and that Vanderlande Industries payed too little attention to these "external influences".

The activity-actor diagram of the current situation (figure 3.5) confirms a lack of attention for the customer's organisation and its environment. The customer is not involved in the actual BHS design process at Vanderlande Industries. After some question time regarding the call for tender document the customer is not contacted anymore until the designed BHS is completed and presented.

Taking a closer look at the IDEF-0 models (appendix D1) of the current situation reveals the lack of the following aspects regarding stakeholders and requirements identification, including questioning the priority:

- A structured approach
- A structured documentation
- Inter-disciplinary communication of results
- Multi-disciplinary evaluation of results

Design choices

In the current design process (illustrated in the IDEF-0 models of appendix D1) no activity is integrated to document the qualitative or quantitative foundation of the choices regarding the BHS concepts which are made. Therefor it is not possible to check whether a BHS concept is designed purely based on expectations or experience of the involved Sales or Systems engineer or on clear foundation. The activity-actor diagram and the IDEF-0 models confirm that the Sales and Systems engineers design the BHS concepts without integrating quantitative dynamic behaviour and cost aspects. So these quantitative arguments are not used in the BHS design process for sure.

Good fit

As mentioned before, a good fit should be established by design choices, based on the total set of requirements or vice versa. Mapping the current situation revealed that the Sales and Systems engineers mainly found their design choices on their own interpretation of the requirements as documented by the customer in the call for tender document. The possibility to influence the total set of requirements and wishes (convincing the customer about certain advantages of design choices) is neglected, proves the lack of communication with the customer or his environment.

Problems allocation

The problems occur at different levels and are related to different aspects, but also overlap. In order to point out in which direction the solutions can be found and which relation the problem has with its environment, these different aspects and levels are made explicit. Therefor three perspectives are distinguished in order to determine the location of the problem(s), analogous to [Sol, 2000a, Meel, van, 1993]:

- The *macro* perspective, concentrating on cooperation between different organisations, in this thesis concentrating on Vanderlande Industries cooperating with the customer and several other external organisations in the sales phase.
- The *meso* perspective, concentrating on coordinating processes that take place within the boundaries of an organisation, in this thesis the different involved departments and Customer Centres of Vanderlande Industries in the sales phase.
- The *micro* perspective, concentrating on the primary tasks that are performed at work place level, in this thesis the primary tasks in the sales phase of the involved engineers, sales men and managers of Vanderlande Industries.

At first this thesis research focussed on the concepting activities of the Sales and Systems engineers (a micro perspective), because the involved employees of the Systems Group (see appendix C) thought the problems concentrated there. Summarising, the underlying problems can only be described by taking a broader view at the sales phase, which results in the following defined problems from a macro, meso and micro perspective:

The problem from a macro perspective:

1) The employees of Vanderlande Industries who are involved in the sales phase of a BHS pay too little attention to the complex context of the decision process of the customer and therefor possibly not make the best of their chances to influence that decision.

The problem from a meso perspective:

2) The employees of different departments and Customer Centres of Vanderlande Industries who are involved in the sales phase of a BHS do not work as a team regarding:
- **The elicitation, interpretation and documentation of information regarding the total set of requirements on a BHS**
- **Structured evaluation of design choices made in the BHS design process**

The problems from a micro perspective:

3) The Sales and Systems engineers of Vanderlande Industries do not adequately document their quantitative or qualitative foundation of the design choices that are made in the design process of a BHS.

4) The Sales and Systems engineers of Vanderlande Industries seldom integrate quantitative results of dynamic behaviour and cost

4.4 Why is it a problem?

A second question to answer is “Why are the stated problems as defined in the previous section a problem?” In order to locate the (possible) consequences of the problems at Vanderlande Industries more precise, the three perspectives (micro, meso and macro) are used again. This shows that, although a problem is described from a certain perspective, the consequences of that problem have to be described by multiple perspectives. In the following tables the answers to the why-question are given for each stated problem. Besides answers in the business economics field, there are several answers related to management in relation networks [Bruijn, de, Heuvelhof, ten, 1999].

What is the problem? 1) The employees of Vanderlande Industries who are involved in the sales phase of a BHS pay too little attention to the complex context of the decision process of the customer and therefor possibly not make the best of their chances to influence that decision.	
Considered Perspective	**Why is it a problem?**
Macro	If the (dynamic!) arguments, multiformity (between organisations but also within organisations) and interdependencies of different stakeholders are unknown in the decision process of the customer, it is not possible to predict the reaction on a offered BHS concept (e.g. aversion to the proposed system from "hidden" and therefor not involved stakeholders). Besides, it is not possible to exchange weaknesses with strengths, to create win-win situations or to lobby in the right way. This lack of grip on the sales decision process of the customer can lead to a stagnating or even decreasing number of system orders, which threatens the continuation of the company.
Micro	Not knowing who the real decision-makers are, including their requirements, in a customer organisation (or an third party organisation with great influence) can lead to tuning the BHS characteristics or peripheral events to the wrong requirements (which can result in losing the contract award).

Table 4.1 Consequences of problem 1.

What is the problem? 2) The employees of different departments and Customer Centres of Vanderlande Industries who are involved in the sales phase of a BHS do not work as a team regarding: - The elicitation, interpretation and documentation of information regarding the total set of requirements on a BHS - Structured evaluation of design choices made in the BHS design process.	
Considered Perspective	**Why is it a problem?**
Macro	This can result in damaging the professional appearance of Vanderlande Industries, by: 1) Asking the same questions to the customer more then once (redundancy) 2) Different interpretation of the same information by employees, communicated with the customer 3) Different BHS concept solutions for more or less similar situations
Meso	Without team-based information elicitation work can be done twice (inefficient). Inconsistency in the interpretations and documentation of the information also results in inefficient cooperation of the involved engineers by misfits of intermediary products (lack off an equal goal).
Micro	The Sales or Systems engineer founds his choices made in the BHS design process only on his own assumptions, expectations, experience and preferences. Therefor it is possible that certain design directions are not considered which can lead to sub-optimal BHS concepts.

Table 4.2 Consequences of problem 2.

What is the problem? 3) The Sales and Systems engineers of Vanderlande Industries do not adequately document their quantitative or qualitative foundation of the design choices that are made in the design process of a BHS.	
Considered Perspective	**Why is it a problem?**
Macro	A lack of documented design choices foundation can undermine the professional appearance to external parties (e.g. if a Sales man presents a BHS concept to a customer without knowing why certain choices are made by a Systems engineer). Besides there are no checks possible whether Vanderlande Industries adapts to the dynamic environment.
Meso	Lack of a documented foundation means no possibility of structured, team-based and efficient evaluation of design choices. It also discourages cooperation (because the origin of design choices are unclear to employees of other departments) and increases the chance for double work (same considerations regarding the design choices are made by different employees). Finally the lack of foundation of choices makes taking over someone else his work quite difficult.
Micro	The Sales and Systems engineers do not have the opportunity to reuse earlier work (because the background information is missing). Inexperienced engineers miss the opportunity to learn from the work performed in earlier projects by more experienced engineers.

Table 4.3 Consequences of problem 3.

What is the problem? 4) The Sales and Systems engineers of Vanderlande Industries seldom integrate quantitative results of dynamic behaviour and cost analysis in the BHS design process.	
Considered Perspective	**Why is it a problem?**
Meso	More objective, quantified foundation of the design choices stimulates an effective and quick team-based evaluation of those choices.
Micro	If a BHS gets more complex, a static calculation does not offer enough insight in the BHS behaviour. This can result in sub-optimal design choices and increased chances for BHS concept adjustments in phases after the BHS concepting (unnecessary iterations) which leads to a longer total development process. This can also be the result when taking the cost aspects into consideration only in a final stage of the design process.

Table 4.4 Consequences of problem 4.

4.5 The need for a new design methodology

This research effort is focused on improving the way BHS are designed in the sales phase of Vanderlande Industries, mainly by taking a closer look at the information elicitation, documentation, sharing, maintenance and usage. Resuming the previous sections, the initial approach of the problems (considering the primary concepting tasks of the Sales and Systems engineers only, the micro perspective) will not result in complete elimination of the problems. The solution must be found by an approach that integrates the micro, meso and macro perspectives.

The stated problems not only have a “hard”, rational side (the BHS equipment and configuration, the tender document offered to the customer, etc.), but also a “soft”, intangible side (customer personal preferences, hidden assumptions, double entry agendas, the engineers job satisfaction, etc.). As mentioned in section 3.1 a lot of stakeholders can be involved in a decision process of the customer. All stakeholders have their own objectives and they are interdependent in different ways, with a continuous changing level of certainty. This multiformity setting in a dynamic environment such as the airport business [Sulzmaier, 2001], combined with the technical complexity of a BHS, makes the Sales phase at Vanderlande Industries complex. To find an appropriate solution to the problems, several fields of knowledge have to be covered, such as:

Customer Relation Management (CRM); because almost all information needed in the design process at Vanderlande Industries must be obtained from (communication with) the customer and his environment.

Systems Engineering (SE), defined as the effective application of scientific and engineering efforts to transform an operational need into a defined system configuration through the top-down iterative process of requirements definition, functional analysis, synthesis, optimisation, design, test and evaluation [Blanchard, 1991, 12]. This approach is relevant because it forms the main lead in the (current) design process at Vanderlande Industries.

Business Engineering (BE), defined as a design perspective on the organisation of the business processes themselves, as well as on the supporting role of ICT in these processes [Meel van, 1993]. Other terms than BE, referring to designing business processes, are Business Process (Re-)design, Business Process (Re)engineering and Business Systems Engineering [Verbraeck, 2000, 5]. In the now-a-days BHS design processes, supporting ICT can not be omitted.

SocioTechnical Design, defined as a design perspective on the integral design of social and technical structures, with the emphasis on organisational change [Meel, van, 94]. Because the problems also include aspects of teamwork, this field of knowledge should be taken in consideration when finding solutions.

Requirements Management, defined as tracking requirements status and change activity and tracing requirements to the various phases and products of the development effort [Young, 2001, 316]. The relevance of the requirements is stressed by the implications of the desired situation (section 4.2), therefor this field of knowledge must be integrated in the solution(s).

Management of change; changing the way BHS are designed at Vanderlande Industries could imply changing (parts of) the organisation. To cope with possible resistance

and to implement changes in the right way, this field of knowledge must be included in the problem tackling activities.

Concurrent Engineering, defined as a design perspective on making the designers aware of all aspects involved in the life-cycle of the system, such as quality, cost, planning and user requirements [Ludema, Roos, 1998]. A broad view on the system requirements (up on which the BHS concepts are based on) means integration of the thoughts of Concurrent Engineering in the design process.

At the start of this project no one could tell what the solution of the problem would look like and which people in the organisation would participate in developing the solution or the solution itself. The most directly concerned engineers in the Systems Group thought of a new way of designing supported by information and communication technology (ICT). The nature of the problems as stated in the previous sections differ and concern the communication culture at Vanderlande Industries and the BHS design methods. Combined with the thought of introducing supporting technology, an integral approach was necessary with attention for the organisation, the processes and the tools. In order to structure such a wide spread solution, a BHS design methodology is developed. A design methodology can be defined as a coherent set of activities, guidelines and techniques that can structure, guide and improve a complex design process [Meel, van, 1993].

Using a framework for the methodology made it possible to comprehend all the different parts of the solution and to attribute them to a logical setting. The introduced distinction between the micro, meso and macro perspective used for structuring the occurring problems (chapter 4) is completed with another analytical framework to structure the solution (the methodology and supporting ICT tools). According to this framework, shown in figure 4.1, a design methodology is characterised by a way of thinking, controlling, working and modelling and can be supported by automated tools [Sol, 2000b].

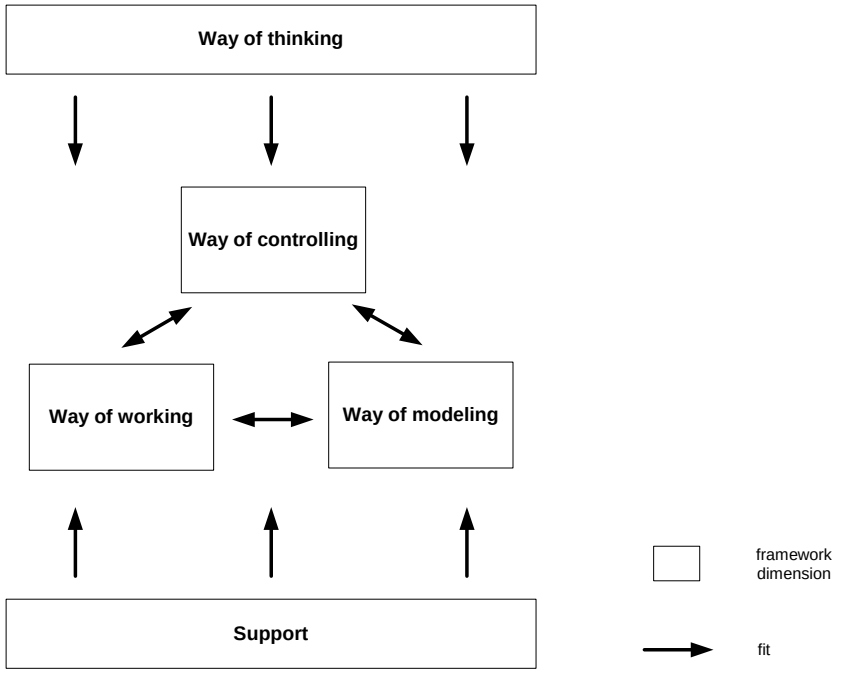


Figure 4.1 The framework: a design methodology and its support [Meel, van, 1993].

Way of thinking

The way of thinking describes the underlying philosophy of the methodology. It can be seen as the filters through which the reality is observed and interpreted.

Way of working

The way of working consists of the tasks of the methodology that have to be performed, such tasks can also be referred to as steps of activities.

Way of controlling

The way of controlling deals with the managerial aspects of the methodology. It includes planning and feedback and determines in which ways various persons and groups should interact.

Way of modelling

The way of modelling defines the design products or intermediate results of the methodology and the way they are represented in terms of modelling formalism.

A ‘good and sound’ design methodology can be defined as a methodology which addresses explicitly the way of thinking, working, modelling and controlling and is supported by a set of automated tools in a coherent and consistent manner [Meel, van, 1993]. This analytical framework is used in a prescriptive way. The four ‘ways’ of the new BHS design methodology are described in the chapter 5. Chapter 6 deals with the supporting tools.

4.6 Summary

The problem analysis can be summarised by the following:
The initial problems as stated in section 2.1, can not quantitatively be proven to exist because of the lack of the required information. Both problems are recognised by all employees who were involved in the master project (see appendix C for names).

The objective as based on these initial problems implies:

- Familiarity with the total set of requirements and wishes (knowing who the potential stakeholders are, what they want and how the requirements and wishes relate to each other.
- Unambiguous, if possible quantified documented design choices made by the Sales and Systems engineers.
- A good adjustment of the design choices to the total set of requirements and wishes or a good adjustment of the total set of requirements and wishes to the design choices.

Based on these implications the following underlying problems are defined:

- Too little attention for the decision process of the customer
- Too little teamwork regarding information processing and evaluation
- No structured and complete documentation of the design choices, including justification
- Seldom integration of quantified results of a dynamic behaviour analysis and cost analysis in an early stage of the design process

The main consequences of these problems are:

- Vanderlande Industries does not maximise her possibilities to influence the decision process of the customer, which can lead to missing orders
- They can damage the professional appearance of Vanderlande Industries
- They can lead to an inefficient design process
- The engineers do not found their designed BHS concepts on a thorough insight which can lead to sub-optimal solutions

The problems cover a wide spread of problem areas so in order to structure the compound solution, a new design methodology is developed. The framework of the methodology includes a way of thinking, working, controlling and modelling and the methodology can be supported by automated tools. The new methodology is described in the following chapter.

5 A new design methodology

In this chapter, the underlying problems as stated in section 4.3 are tackled. At the beginning, the solution directions were based on common sense. The lack of attention for the customer's decision process should be solved by more external communication, analysis of the main process variables and analysis of the involved people. The lack of teamwork should be eliminated by a culture switch at Vanderlande Industries from individuals designing parts of the system to a design team, responsible for the total project. The design activities of the Sales and Systems engineers should include documentation of the design choices and the justification for those choices. In order to make this justification clear and judgeable it should be quantified as much as possible. Two judge two main characteristics of a BHS, being the costs and the performance, these characteristics should be quantified in an early stage of the design process.

These solution directions were discussed with employees and they were asked how they would handle the problems. Besides, literature was consulted to confirm the usefulness of the solution directions and to obtain new perspectives on the solution field. Elaboration of the solutions was discussed with employees of both Vanderlande Industries and the Delft University of Technology. The results are gathered in a new design methodology, which includes a way of thinking (described in section 5.1), a way of working (section 5.2), a way of controlling (section 5.3) and a way of modelling (section 5.4), as described in the section 4.5 of the previous chapter. The findings are summarised in section 5.5.

5.1 Way of thinking

The way of thinking describes the underlying philosophy of the methodology. Again, the macro, meso and micro perspectives are applied to allocate the new way of thinking. Table 5.1 shows the main elements of the way of thinking, which are elaborated in the following sub-sections.

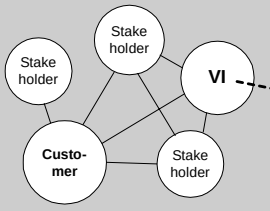
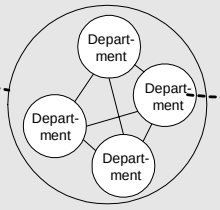
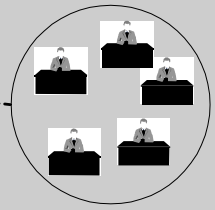
	Macro	Meso	Micro
	 Cooperation of organisations	 Coordination of processes between VI departments	 Primary tasks at workplace level
Way of thinking	"Getting grip on the decision process of the customer"	"Teamwork regarding evaluation and information processing"	"Integral justification including documentation of design choices"

Table 5.1 The way of thinking.

5.1.1 Way of thinking: a macro perspective

The main philosophy regarding the macro perspective is getting a grip on the decision process of the customer, in which the supplier is chosen who will be awarded with the contract. The following notions form this philosophy.

Focus on the customer's needs

As stated in chapter 4 the organisation of Vanderlande Industries is too much focused on the technical side of the Sales phase. Too little attention is spent on the decision process side of the Sales phase. So the engineers of Vanderlande Industries should work less "system focused" and more "customer decision process focused". Satisfying your customer's needs starts with knowing your customer, his business processes and his environment [Hazelrigg, 1996]. That way, you are really capable of judging your BHS concept "through the eyes of your customer" and therefor realise a better fit of the offered concept with the wishes of the decision stakeholders. You are also better capable of showing your customer or another relevant stakeholder that you care about his business and that you think along with them in order to find the best baggage handling solution (in the eyes of the influential stakeholders).

Requirements definition

The definition of requirements starts with studying the customer, his business and the environment. Otherwise the real requirements for the requested solution for a problem can never be determined. In that case chances are big that the system development starts from the wrong point and ends in a system that does not meet the total set of requirements. Several levels of risk are distinguished in such a situation [Hooks, Farry, 2001]:

- Extra design time is required
- Wrong controls or drawings are made
- Wrong products are manufactured
- Wrong products are delivered to customer

In the situation of Vanderlande Industries there is a risk added to the top of this list, being the possibility that the system offered by Vanderlande Industries to the (potential) customer, is not chosen and therefor the contract is not awarded to Vanderlande Industries. So the Vanderlande Industries engineers should integrate an exploration of the customer's environment and the definition of requirements in an early stage of the sales phase in order to provide quality products, as playfully illustrated in figure 5.1.

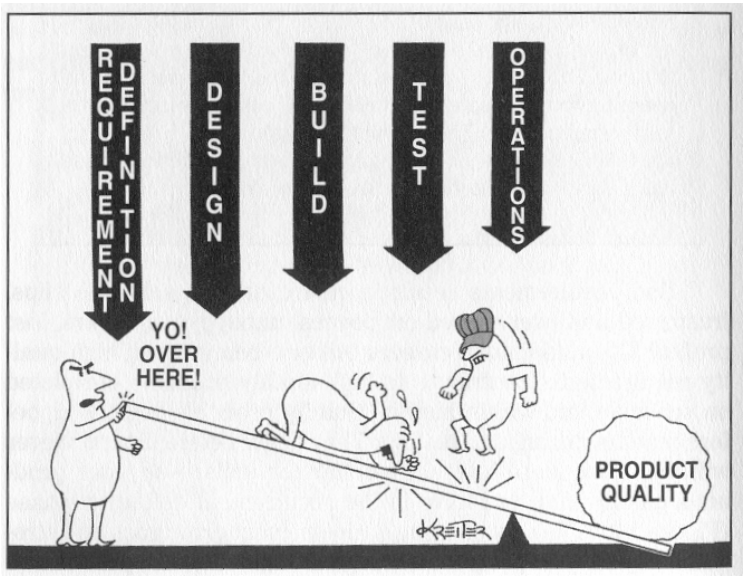


Figure 5.1 Making quality products starts with good product requirements [Hooks, Farry, 2001].

Value by choice

Customers evaluate suppliers, based on their overall satisfaction with the business relationship. A key measure of this satisfaction is the value derived from doing business with a supplier [Byrne, Markham, 1991]. Hazelrigg marks that something has a value to an individual if, under some circumstances, the individual would choose to consume it, that is, if the individual would choose this thing over other options. So value is implied by choice [Hazelrigg, 1996]. Therefor it is important to involve the customer in the design process and create several moments in which the customer's meaning is at least contributory to the chosen direction in the design steps. In the ideal situation, the customer gets the impression that the offered concept by Vanderlande Industries is partly a result of his/her interference. In that case the tendency of the customer to reject the proposed concept decreases. Another advantage of discussing more than one concept of a BHS is that the engineer is able to determine the different requirements of the customer, together with their relevance. Note that there is a difference between involving your customer in the choices you have to make and asking your customer everything. Otherwise the customer can start questioning the professionalism of Vanderlande Industries.

Feedback as instrument

Another way of showing your customer you care about their business is arranging feedback moments during the different phases of a systems life (e.g. development, installation and usage). This is also a good way of gathering and documenting the customers meaning which enables the Vanderlande Industries engineers to learn from the past and monitor changes in the customer expectations.

Coping with the complexity of the stakeholders network

An important aspect of the analysis of complex environments as mentioned in the literature [Enserink, e.a., 1999] is the insight in the range of involved stakeholders, including their interests and perceptions of the situation. Based on that information the stakeholders network can be analysed regarding the interdependencies, balances of power and relationship dynamics. Such an exploration of the customer's environment is called a stakeholder analysis (note that stakeholders can be individual people, departments or organisations who are involved in the total project). The results of a stakeholder analysis support the engineers in handling the following aspects of the complex network situation in the sales phase:

- Multiformity
  The customer exists in all cases of more than one person and, in some cases, of more then one organisation. Understanding of what is going on in the customer's environment and predicting the reactions of the different stakeholders on the proposed system characteristics, helps Vanderlande Industries to deal with the threat of multiformity. This threat is the possibility that stakeholder(s) to whom the system is fit, do not have enough power to make (purchase) decisions [Bruijn, de, Heuvelhof, ten, 1994]. Besides, it helps exploiting the opportunity of multiformity, being the possibility to get awarded with the contract, even with just a small effort, because the right stakeholders were satisfied (touch the right chord).
- Uncertainties
  In an early stage of the sales phase, the stakeholders themselves often cannot make their requirements and performance indicators clear. A stakeholder analysis can then support the concerned Vanderlande Industries employees in weighing the different factors impact and therefor their importance/priority to the stakeholders.
- Interdependencies
  All the stakeholders who are involved (or can be involved!) in the system decision making process are in some way related to each other. Being aware of the interdependencies between the stakeholders (organisations, or different layers within one organisation) offers Vanderlande Industries the opportunity to influence the actions of stakeholders via other stakeholders.
- Strategic behaviour
  If Vanderlande Industries knows all real interests of the stakeholders, it is possible to anticipate on strategic behaviour of the stakeholders. It helps coping with aspects like dual agendas.
- Different perceptions
  When the Vanderlande Industries engineers are able to project themselves in the position of the stakeholders who are involved, they can recognise the different ways of looking at a problem and its possible solutions.
- Closeness
  Every individual and every organisation communicates in a different way with the "outside world". Some are extrovert, communicating and sharing information with their environment. Others are introverted, keeping all information as much as possible for themselves. Understanding how the stakeholders communicate, with external stakeholders but also within the organisation it self, helps

Vanderlande Industries to break through the closeness by approaching the stakeholders in the right way.

- Dynamics
  The world is changing each day. Therefor, the way certain stakeholders were approached in earlier projects might no longer be the right way for the same stakeholder in a new project. An stakeholder analysis, performed for each project, helps Vanderlande Industries to recognise changes that have occurred in the relations and structure of the different stakeholders.
- Linking
  Knowing (most) possible relevant interests of all possible relevant stakeholders enables the engineers (and sales men and agents) to create win-win situations or to compensate weaknesses with strengths.

Awareness and competence regarding customer orientation

These "soft", social-interaction process aspects are less "tangible" then the "hard", content aspects of a BHS. According to Snellen, often the legitimacy of a certain solution is more important than the efficiency and effectiveness [Enserink e.a., 1999]. With other words, the "best" solution is the one every relevant (influential) stakeholder can identify himself with and that does not have to be the best solution from an analytical point of view. So, attention for the customer and his environment is of great importance in the sales phase. In table 5.1 the awareness of the Vanderlande Industries employees of the "soft", customer oriented side is given in relation with the competence in customer focused design. The quadrants represent the different phases in the time.

Competence / Awareness	**Competent**	**Incompetent**
Aware	**3**	**2**
Unaware	**4**	**1**

Table 5.1. Competence and awareness of customer focused activities in relation to time.

Most Vanderlande Industries engineers are now somewhere between phase 1 and 2 (note that this is applicable for the Sales and Systems engineers in general and might not apply to each engineer individually). The awareness of the inadequately attention for the customer oriented way of working sets in (as appears from the CARE project[1]) but the link between the corporal thinking and the individual actions are still missing. The moment the engineers are aware of the incompetence, they can put effort in learning how to work customer environment focused and then will end up in phase 3. After a while,

[1] CARE: Customer Awareness Reinforcement. A project started at VI, leaded by external consultants, to improve the employee's awareness of the importance of customer satisfaction.

working customer focused becomes the standard way of working and the awareness slowly disappears. The engineers do not know better than to concentrate on the customer's environment and phase 4 is reached. But, because of the dynamics of the world outside Vanderlande Industries, new incompetence can be discovered and, if recognised by Vanderlande Industries, the whole process starts all over again.

Integration of a stakeholder analysis and requirement definition in the design process of the Vanderlande Industries engineers could support the transitions from phase 1 to phase 2 and from phase 2 to phase 3.

5.1.2 Way of thinking: a meso perspective

The lack of teamwork regarding evaluation of BHS concepts and information processing, as stated in section 4.3, is approached by the principle of breaking through the walls between departments within the Vanderlande Industries organisation. The following philosophies apply to this principle.

Self-regulating teams

Instead of working separately, the agents, salesmen and concerning engineers should work in a team in order to gather, document and discuss information. This can prevent double work (gathering the same information twice) and stimulates the equal interpretation of information, which results in a smoother adjustment of intermediary products of different departments. Considering the sociotechnical design approach, these teams must function as semi-autonomous work groups [Meel, van 1994] with not only primary tasks (such as calculating a BHS price, analysing the dynamic behaviour of a BHS, etc.), but also managerial tasks (such as planning and controlling a design effort). The "we-feeling" can be enhanced by responsibilities towards each other concerning broader aspects than the aspects directly related to the personal (primary) expertise only.

All disciplines represented

The team-members should represent all disciplines (such as sales, concepting, simulation, calculation, controls and CAD engineering) of a BHS design effort in the Sales phase. Early integration of the different experts not only stimulates the "we-feeling" (all concerned employees involved right from the start of a project), it also offers a broader insight in consequences of design choices which enriches the evaluation moments.

Supporting information system

Such a group wise BHS design effort can be supported by an information system that enables the concerning employees to access the gathered information, stored in one and therefor consistent document. It can also improve the communication between the team-members and offer the possibility to carry out a variety of tasks at one workstation. Although the Vanderlande Industries network (Intranet) offers the possibility to share information with different departments, this cooperation is not structured integrated in the design process.

5.1.3 Way of thinking: a micro perspective

The main underlying philosophy to solve the two problems from the micro perspective (section 4.3) is the integral, if possible quantitative justification, including documentation, of the design choices. This philosophy is a compound of the following thoughts.

Strategic behaviour paradox

The way of thinking from a macro perspective mainly deals with strategic behaviour in a complex network of different stakeholders with different objectives and means. And although the engineers in the current situation focus too much on the system's content only, that content is essential for success (meaning selling BHS). This is the strategic behaviour paradox, as stated by De Bruijn and Ten Heuvelhof [Bruijn, de, Heuvelhof, ten, 1999]: Legitimacy of strategic behaviour depends on justification with regard to the content.

A creative design process

The following design principle of sociotechnical design, which can also be applied to BE [Meel, van, 1994], leads in the prescription of the new situation. This design principle focuses on the compatibility of the processes and the products of those processes. When aimed on designing an organisational structure capable of self-regulation, based on making use of creative individual capacities (the design products), then a constructively participating project structure for the actual design project (the design process) is necessary [Meel, van, 1994]. This means aiming at structuring the creative design process rather than at being prescriptive with respect to the content. In that design process, automated support should free humans from dull and monotonous tasks, thereby freeing intellectual capacity for more complex and creative tasks.

Documentation of design choices justification

If the engineers at Vanderlande Industries document their BHS concept justification well structured, this can offer the following advantages:

- Preventing double work
  There are several engineers involved in the steps from scratch to BHS implementation. Therefor it is very well possible that an engineer doubts the design choices made by another engineer in an earlier step and thinks of changing the solution. If the engineer in the earlier step has documented what went wrong when trying these changes, the other engineer will not try it again.
- Enabling reuse of work
  If the conditions (requirements and constraints) are known that applied to a certain earlier designed BHS, parts of this design can be reused in new BHS.
- Learning individual engineers
  By reading the foundation of the design choices made by experienced engineers, less experienced engineers can learn from their knowledge.
- Learning the Vanderlande Industries organisation

Discussing the justifications of design choices made by individual engineers, enables all Vanderlande Industries engineers to grow towards all-agreed-upon best-practise design choices (sharing knowledge).

- Offering transparency inside Vanderlande Industries
  Transparency of the design choices results in less time necessary to evaluate concepts with colleagues and better possibilities to take over someone else his work.
- Offering power of persuasion
  A complete justification of a concept supports the engineers who present the concept to the customer in reacting on questions and defending certain choices, without the responsible engineer attendant.
- Preventing routine based design
  Justification forces the engineers to explain why certain choices were made. The engineers can then be challenged by colleagues to defend their "routine reasons" during an evaluation meeting.
- Preventing gold-plate
  Justification of the design choices prevents engineers to add extra features to the BHS without real needs.

Integral design

The philosophy of Concurrent Engineering also applies to the "to-be" situation at Vanderlande Industries. The Concurrent Engineering approach is focussed on making the designers aware, right from the start, of all aspects involved in the life-cycle of the system, such as quality, cost, planning and user requirements [Ludema, Roos, 1998]. The quality of a system consists not only of the quality of the components and the configuration of the system itself, but of both that system and its associated processes in designing, building, using and maintaining it over its useful system life.

Justification quantification by simulation experiments

As explained in section 1.2, a bag in a BHS follows a certain sequence of processes, depending on all kind of characteristics of both the bag it self, and the status and number of BHS components. All these relations influence each other, which results in a complex (dynamic) behaviour of the BHS that determines the performance of the BHS. Simulation experiments, offer the engineers quantified characteristics of (proposed) BHS performance. The definition of simulation given by Shannon [Sol, e.a., 1999]:

> *The process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behaviour of the system or of evaluation various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system.*

Using simulation in the design phase in general means that the engineer has the opportunity to test and communicate a concept of a BHS up-front in a computer environment without all the constraints on site and still has all options open for improvements or changes. This leads to cost and risk reduction and saves time during the

latter project phases. In more detail simulation, if used correctly, provides the relevant stakeholders with [Arsham, 2001]:

1. Advanced optimisation techniques (examination of multiple elements simultaneously and track the system performance with respect to e.g. travel times, arrival and exit rates and system utilisation)
2. Insightful system evaluations (experiments to monitor the systems behaviour with particular configurations of input, resource arrangements, flow control rules and downtimes or failures)
3. An accurate depiction of reality (reflects the randomness and interdependencies that system elements share in the complex reality)
4. A good visualisation (animation) of the system (makes corrective feedback possible, can be used as a presentation tool and offers the possibility to track material flows through the system)

The results of simulation experiments can be used for quantitative, conceptual choice foundations, when evaluating BHS concepts. The results in combination with the visualisation of concepts enable the engineers to elicit and prioritise the real requirements of the customer, while presenting several conceptual options (offering choices). Next to the results, the modelling itself and the animation while running a simulation offers the engineer to get good insight in the system's behaviour and suitability of the system for the airport's process. This brings us to the following paradox; A simulation analysis can not be performed without the BHS layout, but in most cases a good BHS layout can not be designed without a simulation analysis. This means that simulation must be integrated in the design process (iteration between layout determination and simulation).

Justification quantification by cost analysis

Figure 5.2 illustrates a typical life cycle of a technical system with on the x-axis the several phases of the system in relation to the time aspect during its life cycle.

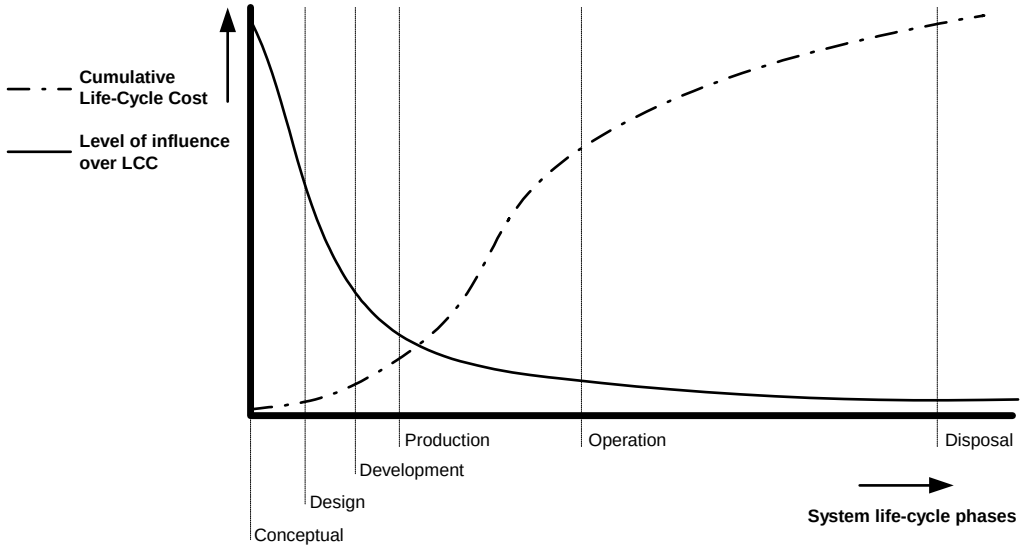


Figure 5.2 Relation between the total Life Cycle Cost and the level of influence over the cost over time.[Source: Ludema, Roos, 1998]

On the y-axis of figure 5.2, represented by a discontinuous line, the cumulative life cycle cost are shown. The continuous line represents the level of influence over the cost that will have to be made in the systems life cycle. This figure shows that, although the cost that have to be made during the conceptual and design phase (the sales phase at Vanderlande Industries) are relatively low, the impact of the decisions made during these phases are of great importance to the total LCC of the system.

Therefor, it is advisable that the engineers of Vanderlande Industries have a feeling for the relationship between their decisions in the sales phase and the impact on the cost that will follow from these decisions. Their decisions influence both the cost that have to be made by Vanderlande Industries (and that will be passed on to the customer, such as R&D and production cost) and the cost that are made directly by the customer (such as the operating cost).

Having an understanding of the life cycle costs (LCC) of a BHS (making a forecast) during the sales phase enables the engineers to:

1. Analyse and evaluate the differences of the cost effectiveness of two or more BHS concepts. The cost effectiveness represents the LCC in relation to the technical characteristics, such as performance, reliability, maintainability, quality and producability [Blanchard, 1991].
2. Present well-founded (quantitative) concepts to the customer
3. Present well-founded (quantitative) concepts to colleagues
4. Project him/herself into the role of the customer (understanding the customer's business)
5. Converge towards more standardisation by designing concepts containing less different component types which results in less spare part storage and less controls development
6. Understand the relationship between their decisions and the "cost drivers" of other departments (getting acquainted with the processes at other employees who are also involved in the same BHS project)

The importance to Vanderlande Industries of LCC is also increasing considering the observed trend of total BHS packages. These packages consist not only of the design, manufacturing and installation of the BHS, but also include maintenance and operation contracts. In these cases Vanderlande Industries needs an overview of the expected LCC in order offer realistic contracts.

Supporting technology

In agreement with the BE paradigm, consideration of possible supporting (information) technology is integrated in the new design methodology (see chapter 6).

5.2 Way of working

The way of working describes the activities that should be performed in the new methodology. These activities are consistent with the way of thinking as described in the

previous section. Table 5.2 shows the activities in relation to the way of thinking. In the first nine subsections, those activities are described that are new or that need extra attention. In subsection 5.2.4 the new overall design process is described which includes the discussed activities, followed by a more detailed description of the design activities of the Sales and Systems engineers.

	Macro Cooperation of organisations	**Meso** Coordination of processes between VI departments	**Micro** Primary tasks at workplace level
Way of thinking	"Getting grip on the decision process of the customer"	"Teamwork regarding evaluation and information processing"	"Integral justification including documentation of design choices"
Way of working	- Lobby - Stakeholders analysis - Requirements analysis - Feedback elicitation	- Team formation - Team based evaluation	- BHS design choices justification & documentation - BHS dynamic behaviour analysis - BHS cost analysis

Table 5.2 The relation between the way of thinking and working.

5.2.1 Way of working: a macro perspective

Summarising the way of thinking from the macro perspective, the employees of Vanderlande Industries should get a (better) grip on the decision process of the customer. The following activities should contribute to that objective.

Lobby

To keep on communicating with the customer and his environment (all possible relevant stakeholders), the lobby must continue during the design process, next to the official meetings and visits. Obviously, the lobby must be performed by the Agent, the Salesman and/or his Area manager. The lobby activity should be included when documenting the team responsibilities. But also other team members and the higher management could lobby and communicate striking news, if those conditions occur.

Stakeholders analysis

To get a grip on the decision-process of the customer, Vanderlande Industries must be acquainted with all stakeholders attendant. The stakeholders analysis starts (long) before the actual decision to quote is made (and a team is formed). It can take years between the moment a first trigger is received that a certain (potential) customer will need a BHS and the moment BHS suppliers are contacted. In this period the Salesman, if applicable in cooperation with a local Agent, must map and document the different players that could be of relevance in the (future) decision process of the customer. Main player of course is the customer's organisation itself. Things to consider are the organisation structure, names of important persons, the balance of power, rights of ownership, company missions, etc. Besides of all relevant stakeholders their characteristics, objectives and means to reach their objectives should be analysed. The structured information document can be used and shared at the team formation to inform all members.

During the total design process the analysis of stakeholders continues. Changes or afterthoughts should be communicated with the responsible team member (e.g. the Salesman) to be added to the analysis. Before a team meeting the analysis results can be send to all members to keep everyone at one line.

Requirements analysis

Regarding the thought of integral design, all requirements and wishes of the stakeholders have to be mapped and documented in a structured way to support all different team members in performing their activities.

The definition of a requirement used in this report is stated as follows [INCOSE, 1993]:

> *If it mandates that something must be accomplished, transformed, produced, or provided, it is a requirement.*

The requirements analysis starts a long time before the first line of a BHS concept is set on paper by the Salesman, in some cases supported by information from a local Agent. At first, the requirements will be rough, such as requiring certain functionality or requiring certain tender procedures. The further the process unfolds, the more detailed the requirements can be.

After a team is formed and a Sales or Systems engineer starts working for a certain project, the requirements documented by the Salesman form the basis. From that moment on the engineer must expand and prioritise the requirements by gathering information (guided by checklists, see section 5.4 and 6.2) and considering the business process of the customer. When the call for tender document is received from the potential customer, the written requirements are added to the analysis results.

During the design process requirements can change, expire or expand. These changes can be detected by all team members and should be reported to the responsible person (e.g. the Sales or Systems engineer). The history of the total set of requirements must also be included in the analysis.

Feedback elicitation

It is advisable to involve the customer or related stakeholders with influence on the decision of the customer in the design process by regular updates or even presentations (if allowed by the legislation regarding public tender procedures). If the conditions occur the customer can even join certain team meetings to evaluate intermediary products. The information gathered during such feedback moments must be reported to the responsible person (agreed upon during the team formation, e.g. the Sales or Systems engineer). He/she documents this information in a structured way (see section 5.4 and 6.2) to make it accessible for all concerned team members.

5.2.2 Way of working: a meso perspective

The way of thinking from the meso perspective comprehends more teamwork regarding evaluation and information processing, which leads to the following activities.

Team formation

The moment Vanderlande Industries decides to make a quotation for a BHS and it concerns a complex system and/or customer environment, a team must be formed by the Salesman (see also the way of controlling, section 5.3). The members of this design team should represent all disciplines that can be involved in early or later phases of the design process of the BHS. Involvement right from the start will increase the commitment to the design effort. The following employees should join the team; a Salesman, a Sales or Systems engineer, a CAD engineer, a Simulation engineer, a Controls engineer, a Calculation engineer and a Project manager (if applicable).

The first thing to do is the documentation of the responsibilities for the different tasks during the design process. Besides the primary tasks, such as drawing the system, writing the tender document and building a simulation model, managerial tasks have to be accomplished by the team members. For example planning and preparation of meetings, adjusting the contents and delivery times of intermediary products, checking the design process progress, information spreading, etc.

Team based evaluation

The moment the team is formed, the actual team based evaluation starts with discussing the initial stakeholders and requirements analysis results. Guided by checklists, the completeness and the correctness of the analysis are discussed. This evaluation must also reveal different interpretations of information in order to get all team members on one line. The evaluation of the completeness and the correctness of the information on which the BHS concept designs are based must be repeated during the sales phase. The number of evaluation moments depends on the dynamics of the environment (such as new stakeholders entering the decision process, new events happening, etc.). The meetings are scheduled ahead (e.g. every two weeks) but can be rescheduled if necessary. When possible relevant stakeholders outside Vanderlande Industries should be invited to join certain evaluation meetings (see also previous comments on feedback elicitation).

During these meetings not only the completeness and correctness of the information the BHS design choices are based on is evaluated, but of course also the choices themselves. When the stakeholders and the requirements (for that moment) are documented properly and the first design choices regarding the BHS concept are made, these decisions can be evaluated. All team members, representing all disciplines and aware of the total set of (agreed upon) requirements, have their own point of view what results in an integral BHS concept design effort.

The results of the evaluations have to be documented. Besides the minutes of meetings the results regarding the design choices and their foundation have to be documented in a structured, consistent way (these templates will be described in section 5.4)

5.2.3 Way of working: a micro perspective

The main thought for the new situation from a micro perspective is the integral justification and documentation of the design choices made in the BHS design process. This implies the following activities:

BHS design choices justification and documentation

The Sales engineer (or Systems engineer, see section 3.1 for clarification) must document the designed BHS concepts and the information he/she uses during the design process in a structured and consistent way. This enables the colleagues to judge the considerations made by the engineer. The engineer must quantify his/her concept choices justification as much as possible (see also following subsections) to support quick and structured team evaluation afterwards. A checklist supports the engineer to integrate many disciplines in the design choice justification. The documented concepts including justification offers the experts of all disciplines to check the engineer's reasoning and to prepare themselves for evaluation meetings.

BHS dynamic behaviour analysis

In the line of integral design and quantification of design choices justification the Sales or Systems engineer must integrate a simulation study when static calculations do not answer all questions regarding performance or system behaviour (necessity of the simulation study can be determined in consultation of a simulation engineer). As stated by Banks a thorough simulation study contains the following steps [Banks, e.a., 1999]:

1. Problem formulation
   The engineer is already involved in the stakeholders and requirements analysis and the conceptual choices that are considered, therefor the uncertainties can be defined and documented.
2. Setting of objectives and overall project plan
   The engineer must determine the objectives of the simulation study. These are the questions to which the answers are to be found. The engineer should also determine, if necessary in consultation of a Simulation engineer, whether simulation is the appropriate methodology for the objectives as stated. Besides the objectives, a planning has to be made and communicated to the design team about which alternatives are to be simulated, how the results are evaluated and how long the study will take.
3. Model conceptualisation
   The initial line diagrams, already designed by the engineer, are used to evaluate different concepts with colleagues in the first place. These diagrams are the conceptualisation of the concept(s) to be simulated.
4. Information collection
   In most situations this step is performed iterative, because while talking about the objectives, building the model and analysing the results, the complexity of the model will changes and therefor the required data will changes. Information about the BHS equipment related input, such as the speed or capacity, can be found in the Vanderlande Industries Product Data Book. If available, the drawing of the terminal building must be integrated in the simulation study to determine layout

possibilities. Information about required baggage flows, different scenarios and redundancy must be collected and documented in a structured way (see section 5.4) and verified with customer and colleagues.

5. Model specification

   The engineer now has to translate the conceptual model and the information into a simulation model (for modelling technique see section 5.4).

6. Verification

   Before using the model the engineer should check the coding of the model. By using common sense while observing the animation of a running model bugs in the input parameters and model structure can be traced and corrected. The output has to match with rough estimations (e.g. a static calculation). If it does not match as expected, the way the results are calculated should be corrected.

7. Validation

   In this step the engineer must make sure that the model reflects the reality in the right way. This can be done by changing input parameters and test the reaction of the model. Is it the expected reaction? Another way of validating the model is by presenting the animation and results to colleagues, familiar with baggage handling processes.

8. Experimental design

   Now that the model is ready to produce useful output, the engineer has to document the scenarios that have to be simulated. Often, new (combination of) scenarios will reveal while analysing earlier runs. The engineer also has to decide how long the simulation run will be and when stochastic input is used, it is necessary to base the results on several replication runs instead of only one. The Sales or Systems engineer can consult a Simulation engineer from the Systems Group if knowledge about certain steps is insufficient.

9. Production runs and analysis

   The actual runs are performed and the result must be analysed.

10. Determination more runs

    Based on the analysis results, the engineer might be interested in other alternatives of the BHS. If so, parts of the existing model can in most cases be reused when building new models of other alternatives.

11. Documentation and reporting

    In order to make evaluation in a team possible, the engineer must document the results of the simulation runs. Besides the results, the input parameters used and the assumptions made during building the model should be documented. This enhances the understanding and therefor the trust of the team members in the simulation effort when presenting and discussing it.

12. Implementation

    Considering the sales phase of Vanderlande Industries, this step should be the choice of the BHS concept (or concepts) which all team members will work on from that moment on.

BHS cost analysis

In line of the integral design thought, the Sales (or Systems) engineer should integrate the cost aspects in the justification of the BHS concept design. To simplify the evaluation of

design choices in the team meetings, the engineer must quantify the cost aspect as detailed as necessary, depending on the phase of the design process. Therefor the engineer must calculate and document (if necessary in consultation with a Calculation engineer) costs related to the BHS concepts. The costs can be divided in several cost elements (see section 5.4). During team meetings the relevance of each element must be clarified to determine the time that can be spend on the calculations.

5.2.4 The new overall BHS design process in the sales phase

All activities of the previous sub-sections are brought together in the new design process, based on the iterative process steps of Systems Engineering (requirements definition, functional analysis, synthesis, optimisation, design, test and evaluation [Blanchard, 1991, 12]. Figure 5.3 presents the activity-actor diagram of the new situation. This diagram mainly clarifies the changes from the macro and meso perspective. The micro perspective is considered in the IDEF-0 models (included in appendix D2) and described in sub-section 5.2.5.

The boxes of the activity-actor diagram contain the activities that should be performed. In this diagram, the columns represent the expertise of a certain discipline, not necessarily an engineer of that discipline (e.g. calculation of a system price can be done on different levels of detail, not necessarily by a calculation engineer).

Stakeholders and requirements analysis

The first step taken by Vanderlande Industries, analysing and documenting the stakeholders and the initial requirements, starts long before the customer writes the call for tender. It can take years before the customer actually tenders, after a long time of speaking to different parties and letting the world know that a new BHS will be required. During these years the Vanderlande Industries sales department should already get a grip on the situation by making people familiar with the name Vanderlande Industries and knowing who is who including the different relationships and interdependencies. So the sales man needs to start the analysis of the different stakeholders and their requirements in a early stage, because often there are only two months left after the call for tender is obtained to design the BHS and write the tender document.

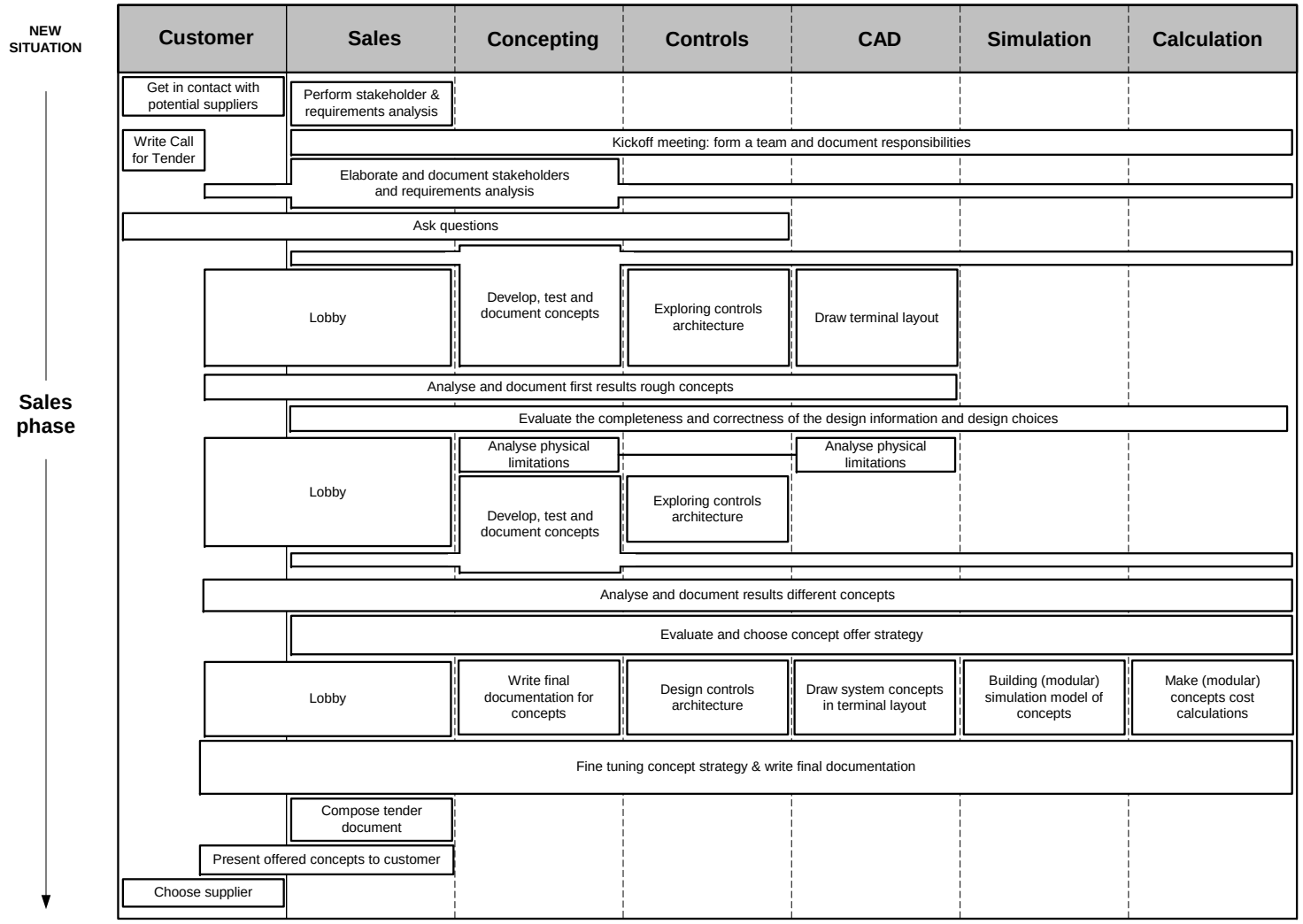


Figure 5.3 Activity-actor diagram of the new situation in the BHS concept design.

Kickoff meeting

The moment Vanderlande Industries decides to make a quotation a team is formed and the responsibilities of each team member are documented. Also those engineers who will not be busy right from the start of the project (e.g. the simulation and calculation engineer) are involved in the team in order to create commitment to the project. The sales man makes the first documented stakeholder and requirement analysis results available, including a project number.

Analysis elaboration and asking questions

After the kickoff meeting the involved Sales men, the Sales or Systems engineers and the Controls engineers together start up a thoroughly analysis and document the stakeholders and requirements. When the call for tender is received they document in a team-based effort the requirements and discuss the interpretation. Communication with the customer (official in a question round or by unofficial lobby) must clarify the missing parts of the stakeholder and requirements analysis.

First design round

After the analysis results are base lined Sales or Systems engineers (the concepting discipline) start developing BHS concepts (further detailed in section 5.2.5). This is done in close consultation with the Controls and CAD engineers, who start working on possible control architectures and the terminal building layout. In the mean time the Salesmen (and Agents) stay involved in the customer's environment in order to detect relevant changes in participating stakeholders and their requirements on the BHS. When different concepts are designed, they are evaluated by the team, based on their relations with the stated, documented and agreed upon requirements. In some cases, e.g. when the European legislation regarding public tender procedures applies, no or very little contact with the customer is allowed. Questions may be asked to the customer, but only if officially written down and the answers will be sent to all competitors. In such situation it can be preferable not to involve the customer officially, because it might result in competitors copying the solutions of Vanderlande Industries. While evaluating different BHS concepts, the involved Vanderlande Industries employees must also discuss and tailor the content of the checklists to the specific project.

Following design round(s)

Then, a new design round can be performed. Note that filling, maintaining and evaluating the stakeholders analysis, the requirements analysis and the designed concepts will be an iterative process. These activities can not be fixed scheduled up front because they depend on the dynamics of the sales phase (e.g. stakeholders who enter or leave the sales process, changing political situations, intermediary evaluations, etc.). However, the inter-colleague evaluations have to be performed, therefor it is wise to document agreed upon evaluation moments in the sales phase. These moments can be rescheduled when necessary.

Concept offer strategy choice

After iteration in designing and evaluating concepts, a moment will come to choose the concept, concepts or the concept strategy that will be offered to the customer. In almost all situations Vanderlande Industries must offer at least one concept that is fully compliant with the official requirements as stated in the call for tender. Otherwise Vanderlande Industries enlarges the risk of being excluded from the list of potential suppliers based on non-compliancy. If Vanderlande Industries beliefs a concept can be offered to the customer that is not fully compliant but will (in the eyes of Vanderlande Industries) satisfy the needs of the customer in a better way, this concept can be offered together with the fully compliance concept. This way the customer can justify to the outside world further cooperation with Vanderlande Industries based on the fully compliant concept, but can also discuss the potential better option. Vanderlande Industries may also choose for offering a concept strategy, for instance modular concept options. A modular concept offer is compliant to the requirements, but also includes defined omissions or extensions regarding technology and/or functionality together with a cost/benefit analysis.

BHS concept elaboration

When the choice, based on team discussion, is made which concept strategy to offer, the engineers start fine tuning the concept(s) and writing the final documentation. The Controls engineers will start designing the control system and the Calculation engineer will make detailed “selling-price” calculations, based on the CAD drawing of the concept made by the CAD engineer. The Simulation engineer will build a detailed model of the concept in order to proof the customer that the claimed performances can be met.

Tender presentation

Based on the outcomes of the different engineering activities there is a latest opportunity to adjust certain parts of the system concept, before the results are gathered in the tender document and (if permitted) presented to the customer.

The moment the customer decides who can be the supplier, the build phase starts (not included in figure 5.3. In this phase, the Vanderlande Industries project manager should elicit, evaluate and document feedback from the customer and make sure that this information reaches the concerning engineers.

5.2.5 The new BHS design process of the Sales and Systems engineer

This subsection contains the textual description of the new design procedure of the Sales and Systems engineers. Besides this text there are IDEF-0 models included in appendix D2 for further explanation. These models divide the activities in sub-activities to zoom in for more detail. These IDEF-0 models include some new supporting tools that are further explained in chapter 6.

Gather and document information

The actual concepting activity starts with gathering information (IDEF-0 level N_A2.1). The first information about relevant stakeholders and their requirements is obtained from the analysis results, documented by the Sales man. In conversations with the Sales man lacks of clarity can be filled and a mental model of the problem is formed. Then, in an iterative process, the Sales engineer collects information from the Internet (e.g. characteristics and missions of the airport), the Vanderlande Industries Network, potential sub-contractors, the call for tender document, colleagues and of course the customer. The way the "voice-of-the-customer-input" is obtained during the design effort must be defined and documented. The engineers must complete the constraints and requirements with priority attributes and ID codes to trace them through the design effort. In consultation with colleagues the analysis is evaluated. When a satisfying level of completeness and correctness has been reached, the results can be base lined and the development of potential BHS concepts starts.

Design possible BHS concepts

The development (IDEF-0 level N_A2.2) begins by defining and documenting the required functionality and baggage flows. Then for each functionality area the potential technology must be determined. After documentation of the conceptual systems, another evaluation round can be performed with colleagues to discuss the designed concepts in relation to the requirements on the system. Also the relevant stakeholders outside Vanderlande Industries can be involved in this evaluation, if allowed by the legislation regarding public tender procedures. Note that the results of the stakeholders analysis can be "unpleasant" for some stakeholders (for instance some personal characteristics and objectives). Therefor it is preferable only to lift some elements out of the analysis when directly evaluated with people outside Vanderlande Industries.

Determine and document dynamic behaviour

If viable BHS concepts are selected (e.g. two options completely compliant to the customer requirements and one "smarter" option, not fully compliant) the dynamic behaviour, if point of discussion, is determined (see sub-section 5.2.4). The required level of detail to obtain the right information can be discussed with a Simulation engineer. After running scenarios and analysing the output, the results are summarised and documented, including the layout of the concept.

Calculate and document costs

To evaluate the concepts regarding cost, cost calculations (not too detailed) are performed by the Sales or Systems engineer. If there is a lack of input data for the cost calculation, colleagues must be consulted to get reliable and agreed upon results that are documented.

Evaluate and document

Again, in an iterative way of working, the results are evaluated with colleagues and if applicable with other relevant stakeholders. The design team can evaluate the BHS concepts by tracing (and approving) the relevant requirements for the designed concept characteristics. Based on the outcome the quotation strategy is determined. The engineer

ends the sales phase by elaborating and documenting the final concept(s) and by preparing the descriptive text for the tender document.

5.3 Way of controlling

The way of controlling deals with the managerial aspects of the new design methodology. Because of the overlap of the way of controlling from macro, meso and micro perspectives, these perspectives are not made explicit. Table 5.3 shows the relation between the way of thinking, way of working and the aspects of the way of controlling as introduced in this section.

	Macro Cooperation of organisations	**Meso** Coordination of processes between VI departments	**Micro** Primary tasks at workplace level
Way of thinking	"Getting grip on the decision process of the customer"	"Teamwork regarding evaluation and information processing"	"Integral justification including documentation of design choices"
Way of working	- Lobby - Stakeholders analysis - Requirements analysis - Feedback elicitation	- Team formation - Team based evaluation	- BHS design choices justification & documentation - BHS dynamic behaviour analysis - BHS cost analysis
Way of controlling	← Process manager → ← Commitment → ← Drop out prevention → ← Support → ← Responsibilities division & documentation →		

Table 5.3 Relations between the way of thinking, working and controlling.

Note that the way of controlling as described in this section is meant for the managerial aspects once the new design methodology is implemented at Vanderlande Industries. The aspects regarding the implementation are dealt with in chapter 8.

5.3.1 Introduction of a process manager

A new role is introduced in the BHS design effort at Vanderlande Industries, the role of process manager. The process manager's main job from macro and meso point of view, is to find the right balance between the "process" and the "content" side during the design effort (see also the strategic behaviour paradox as stated in section 5.1.3; legitimacy of strategic behaviour depends on justification with regard to the content). The process side refers to the decision-process of the customer. The content side refers to the BHS concept (the configuration, the used technology, performance, etc.).

Reasoned by analogy the expert strategy, participative strategy and adaptive strategy as defined in [Meel, van, 1993] apply here. The expert strategy means that Vanderlande Industries designs the BHS all by itself. That is efficient but the acceptation

of the design will be hard because of the “not invented here syndrome”. The opposite is the participative strategy; all design choices are made by all stakeholders themselves and are based on consensus between the stakeholders. The acceptation will improve, but the design process will not be efficient. Therefor the best is a mix between these strategies, called the adaptive strategy. Stakeholders (including the customer) can learn from Vanderlande Industries and vice versa. For effective learning a close corporation between all stakeholders and Vanderlande Industries is needed in all phases of the design process. Stakeholders outside Vanderlande Industries often have much knowledge of organisational business processes, bottlenecks in current functioning and possible improvements. Vanderlande Industries brings in knowledge about the design methodologies, techniques and tools and can suggest possible overlooked alternatives.

So the process manager must control this alternation in the design process. This means attention (evaluation) for both the completeness and correctness of the stakeholders and requirements analysis (this includes the lobby, feedback and evaluation activities) and for the justification of the design choices that are made. An important aspect of the “process” side is the attention not only for the external communication, but also the vertical communication within the Vanderlande Industries organisation (involvement of the higher management).

The role of process manager can be fulfilled by the Project manager. If no Project manager is applied in the project, the role can be performed by the Manager Sales Engineering (regarding the design choices justification) and the Area manager (regarding the stakeholders and requirements analysis).

5.3.2 Support

From the macro perspective, support must be created for the way of cooperation between Vanderlande Industries and other stakeholders in the decision process of the customer. Therefor Vanderlande Industries must communicate a suggested cooperation approach for each stakeholder individually (or combined agreements) at the beginning of the design effort. Regarding the coordination of the processes between the different departments (meso perspective), the process manager must ensure that the team members (and therefor the departments) understand and support the way they work together. If not, another approach must be formulated and documented. For both perspectives it is important to get the support of the management of Vanderlande Industries too, by communication and involvement.

From the micro perspective, the (design) process manager at Vanderlande Industries must ensure that all team members support the methods and tools that will be used during the design effort. Acceptance of the methods and tools will increase the trust in the (intermediary) design results.

5.3.3 Commitment

The process manager must ensure that all design team members, keep committed to the team based design effort. If the “we-feeling” fails for certain involved people, the process manager should found out the reason and discuss this dissatisfaction regarding the teamwork. Dissatisfaction can be detected by frequent absence at team meetings or a lack of communication. Besides the team, it is very important to keep the management of Vanderlande Industries committed to, e.g. by frequently communicating up-dates of the design effort or involvement in team meetings or evaluations.

For some projects, external stakeholders such as the customer or a consultant are integrated in the design effort, or even the design team at Vanderlande Industries. In these cases the process manager must ensure that these stakeholders stay committed by frequent communication and information sharing.

5.3.4 Drop out prevention

Vanderlande Industries is one of the stakeholders in the decision process of the customer. Several stakeholders, such as the customer and the consultant of the customer, play a crucial role in the information supply for the design process at Vanderlande Industries. Therefor, communication with these stakeholders is very important and Vanderlande Industries must prevent that one or more stakeholders stop communicating. This can be achieved by convincing the stakeholders that their opinion really matters and influences the BHS design. Realising that their remarks are heard and they really have possibilities to influence the BHS design prevents these stakeholders to shut the door for employees of Vanderlande Industries.

From a meso perspective, the process manager must prevent that certain team members drop out of the team (never show up at meetings and avoiding communication with other members). This can be realised by delegating not only the primary design tasks, but also managerial tasks regarding the team functioning such as preparation of meetings, planning and evaluation tasks.

5.3.5 Responsibility division and documentation

In order to clarify the responsibilities of the activities in the design effort and to create the possibility to verify the results, the responsibilities have to be divided, documented and delegated to the different team members. Besides for the activities already included in the current design process, the responsibilities for the activities as stated in the way of working have to be allocated during the team meetings.

Team formation

The team must be formed by the Salesman (final responsibility of the Area manager), involving the colleagues as mentioned in sub-section 5.2.1. In the first kickoff meeting of

that team, the responsibilities for all activities as planned in the design effort have to be allocated and documented, including the planning.

Lobby

Lobby takes place at several levels. Besides the Agent, the Salesman and the Areamanager also other team members or members of the higher management can lobby. The process manager must take care of the adjustment and the frequency of the lobby activities. The exchange of relevant information gained during lobby should happen via the process manager (he/she must judge whether information can be documented or not).

Stakeholders analysis

The Salesman must start the stakeholders analysis the moment he/she, or a Agent, discovers a potential market. The analysis results are reported to the Area manager. The results at the moment of the team formation enable the other team members to study the situation (preparation on the kick-off meeting). During the total project the Salesman is the main responsible for the stakeholders analysis. Changes or additions discovered by others should be documented via the Salesman. The process manager must enable frequent team-based evaluation of the stakeholders' results. Both the composition and the evaluations are guided by a template (checklist).

Requirements analysis

The requirements on a BHS start at an abstract level and get more and more detailed during the sales phase. The initial requirements can be formulated even before the design team at Vanderlande Industries is formed. These requirements have to be documented by the Salesman. The moment a Sales or Systems engineers starts working on the project he/she accounts for the requirements analysis. All changes or additions in the requirements discovered by others have to be documented by the responsible Sales or Systems engineer. In comparison with the stakeholders analysis the documented results form preparation information for the team meetings and the composition and evaluation are guided by a "sound-requirements-analysis-template".

Feedback elicitation

The process manager is responsible for the (delegation of) adjustment and frequency of the feedback activities, including structured sharing of the results. It is advisable to document the obtained feedback via one person, e.g. the Salesman.

Team based evaluation

The process manager is responsible for frequent and structured team based evaluation moments. Especially in case of a (very) dynamic environment, regularly recapitulation of the information the design effort is based on is necessary. Templates can quicken and guide the structured evaluation activities.

BHS design choices justification and documentation

The Sales and Systems engineers have to document their justification of the design choices they make during the sales phase. A template for complete documentation of the choices enables the team members to study on the choices and the information they are

based on, e.g. just before an evaluation meeting. This way all team members are acquainted with the progress and can call the concerning engineer to account for incorrect or incomplete justification.

BHS dynamic behaviour analysis

The dynamic behaviour analysis can be part of the justification of the design choices. If such an analysis is required (determined by the Sales or Systems engineer in consultation with a Simulation engineer or/and by other team members) to complete the justification template of the BHS concept, the Sales or Systems engineer is responsible for all steps as mentioned in sub-section 5.2.8.

Cost analysis

Similar to the dynamic behaviour analysis, completeness and correctness can require integration of cost analysis results in the justification of a BHS concept. So this is also the responsibility of the concerning Sales or Systems engineer, checked by the team members during evaluation moments.

5.4 Way of modelling

The way of modelling describes the types of models (substitutes for the complex reality) and techniques that form the (intermediary-) results of the BHS design effort. Besides the existing modelling techniques of the current design process (see section 3.2), new models are applied in the new activities and described in this section. Table 5.4 shows the new models in relation with the way of thinking, working and controlling.

	Macro Cooperation of organisations	**Meso** Coordination of processes between VI departments	**Micro** Primary tasks at workplace level
Way of thinking	"Getting grip on the decision process of the customer"	"Teamwork regarding evaluation and information processing"	"Integral justification including documentation of design choices"
Way of working	- Lobby - Stakeholders analysis - Requirements analysis - Feedback elicitation	- Team formation - Team based evaluation	- BHS design choices justification & documentation - BHS dynamic behaviour analysis - BHS cost analysis
Way of controlling	Process manager Commitment Drop out prevention Support Responsibilities division & documentation		
Way of modelling	Stakeholders analysis template Requirements analysis template	BHS concept design choices justification	BHS concept description template Simulation model Cost breakdown structure

Table 5.4 Relations between the way of thinking, working, controlling and modelling.

The first two sub-sections discuss templates to structure the stakeholders and requirements analysis. Sub-section 5.4.3 discusses the template to document a BHS concept in a structured way. The fourth sub-section describes the way the justification of the design choices made during the BHS concepting is modelled. This is followed by the simulation model used in the dynamic behaviour analysis activity and finally the structure of the cost breakdown model is discussed, which can be used in the cost analysis activity.

5.4.1 Stakeholders analysis template

To guide a complete stakeholders analysis and the evaluation of this analysis in the new design methodology, a template is composed for the documentation of a stakeholders network. It guides the engineers and Salesmen in documenting all relevant stakeholders who can have an influence on how the quality of a BHS is experienced. By taking all wishes and requirements into consideration, a better weighing of pro's and con's of BHS concepts can be made (and no important factors are omitted). Filling of the stakeholders analysis template will be performed iterative because, in the initial contact phase, not all the information is available yet.
The list below contains all items that are included in the stakeholders analysis template. Note that for each item, several hints are included to guide the filling (see section 6.2)

1) Initial problem description
   The initial problem (or current/required situation) as stated by the customer
2) Organisation chart of the customer's organisation
   Including persons' names and communication lines.
3) Stakeholders
   Including ID (initials), organisation name, department, person's name, function, telephone number and e-mail address.
4) Stakeholders' characteristics
   Comments about the stakeholders that should be shared with other colleagues, such as experience with Vanderlande Industries, relationship, level of BHS knowledge, etc.
5) Stakeholders' objectives and perspectives
   The fundamental objectives (stabile in time, mostly abstractly formulated) of the stakeholder and the concrete objectives (concrete issues) for this project. And what is the perception of the problem and solution of the stakeholder, depending on e.g. the cultural background, position, ambition, fundamental objectives, available vocabulary (what can be discussed) and individual frame of reference (selective perception).
6) Stakeholders' means
   The means, both formal and informal, the stakeholder can deploy in order to reach the objectives (technical, juridical, social or economical). And is the stakeholder a formal, informal or no decision maker in the project?
7) Stakeholders interdependencies
   The way the involved stakeholders are interdependent, e.g. on resources, information, relations (both formal and informal) and balances of power.

8) Communication agreements
   The agreements made regarding communication.
9) Meetings overview
   Including Vanderlande Industries employee and stakeholders ID's, meeting date, meeting subject, results and references.
10) Other communication (than meeting) overview
    Including Vanderlande Industries employee and stakeholders ID's, date, subject, results and references.
11) Strategy in stakeholders approach
    The agreed upon approach of stakeholders regarding technology, economics, management and communication: such as involve in process, emphasise new technology, emphasise other project references, emphasise proven technology, emphasise good relation, emphasise extendability, emphasise LCC, emphasise low noise, offer more then one concept options, offer certain quality/price balance, emphasise or keep silent about certain risks, etc.
12) General comments
    All comments about the sales process that can not be classified in one of the previous items, including author ID, date and comment description.

5.4.2 Requirements analysis template

Another template introduced in the new design methodology is the requirements template. It guides the involved Vanderlande Industries employees in documenting the total set of requirements and constraints that apply to the concerning project. The template is divided in five parts: introduction, general functionality and technology requirements, constraints, specific BHS requirements and procedural requirements.

Introduction

The introduction of the template contains the characteristics of "quality requirements". For each requirement entered, the involved engineer or sales man can evaluate the requirements' quality by the following characteristics [Young, 2001, Hooks,Farry, 2001]:

1) Complete
   Nothing is missing (no "to be determined") and all conditions under which the requirements stated applies.
2) Consistent
   Does not conflict with other requirements.
3) Correct
   Accurately states a customer need.
4) Feasible
   Can be implemented within known constraints.
5) Modifiable
   Can be easily changed, with history, when necessary.
6) Necessary
   Documents something a stakeholder really needs.
7) Prioritised

Ranked as to importance of inclusion in product.

8) Testable
   Possible to ensure that the requirement is met.
9) Traceable
   Origin (source) of requirements known.
10) Unambiguous
    Has only one possible meaning/interpretation.

Also included in the introduction is the protocol for coding and documenting different versions of requirements and constraints (see chapter 6 / appendix E).

General functionality and technology requirements

After the introduction the general functionality and technology requirements are included. Each documented functionality requirement owns these attributes: author initials, requirement ID code, requirement description, initials of the person/organisation to whom the requirement is assigned to, compliance level, Vanderlande Industries priority and comments. The prioritisation of the requirements before spending resources on them, offers greater flexibility in tradeoffs, design and implementation [Hooks, Farry, 2001]. They are grouped per functionality area and are divided in check-in, transport, sorting, make-up, break, HBS, EBS, controls, consolidation and other.

Constraints

The constraints in the requirements template are grouped in:

1) Existing BHS constraints
2) Knowledge constraints
3) Terminal building constraints
4) Environmental constraints
5) Vanderlande Industries constraints
6) Competition constraints

The only differences between the attributes of the functionality requirements and the attributes of the constraints are the requirement ID that is replaced by a constraint ID and the compliance level that is replaced by a rigidity level.

Specific BHS requirements

The specific BHS requirements are divided in:

1) Flow requirements
2) Operation time requirements
3) Performance requirements
4) Redundancy requirements
5) Flexibility requirements
6) Conveyability requirements
7) Controllability requirements
8) Maintainability requirements
9) Safety requirements
10) Ergonomics requirements

11) Life cycle cost requirements

The attributes of these requirements are similar with the attributes of the functionality requirements.

Procedural requirements

The final part of the template contains a checklist for procedural requirements (e.g. the tender document content and layout, the project planning, relevant legislation concerning tender procedures, etc.).

5.4.3 BHS concept description template

The structured documentation of a BHS concept (the design choices) is guided by a template containing the following:

1) Concept layout
   (import of the material flow diagram, the line diagram, a drawing and/or another 2D/3D system representation)
2) Technology specification
   (includes the same functionality areas as the functionality and technology requirements in the requirements template)
3) Cost effectiveness
   (includes throughput, in-system-times, resource utilisation, redundancy, maintainability, reliability, availability, flexibility, controllability, safety, ergonomics and life cycle cost, compare [Blanchard, 1991])
4) References
   (includes document name, description and location)

5.4.4 BHS concept design choices justification

The justification of a choice made in the design process exists of a description of the choice including the foundation (the reason). The description of the choices is included in the template for BHS concepts as described in the previous sub-section. The foundation can be formed by referring to the requirements on those parts of the systems that are affected by the concerning choice. Tracing the requirements, a main issue of Requirements Management, is the technique used to provide relationships between requirements, design and implementation of a system in order to manage the effect of change and ensure the success of the delivered system. These relationships are the justification of the designed system by linking the systems characteristics with the requirements as stated by the stakeholders. Figure 5.4 shows the relations between these elements.

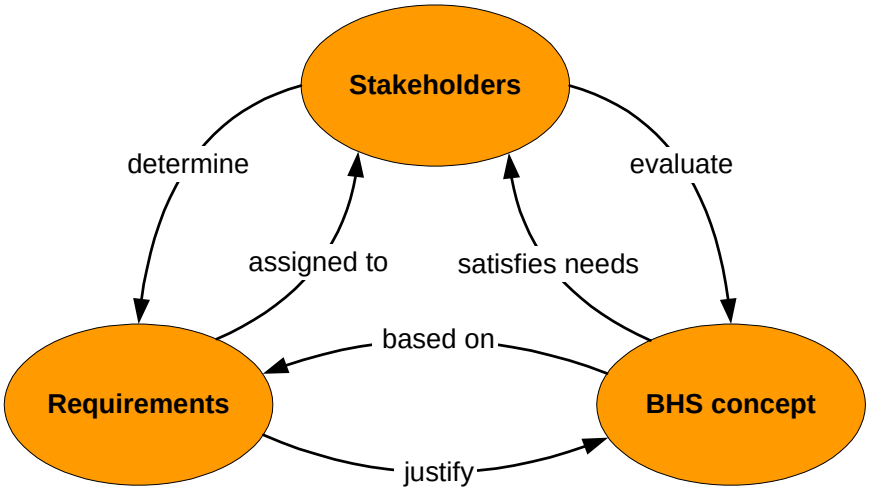


Figure 5.4 Relations between the stakeholders, the BHS concept and the requirements.

These relations are modelled in the earlier mentioned templates for the requirements analysis and the BHS concept documentation. For each documented requirement, the stakeholder who determined that requirement is included with the priority that stakeholder assigns to the requirements and the priority in the eyes of Vanderlande Industries.

5.4.5 Simulation model

The combination of different processes (such as scanning, screening, transport, storage and sorting, see section 1.2) in a BHS that influence each other make the systems to complex to analyse the behaviour by analytical techniques only. Therefor, the dynamic behaviour analysis is supported by the making of a simulation model of the BHS concept. Because of the characteristics of baggage handling (bags entering the (sub-)systems one after the other) a discrete event simulation model is chosen. Animation is used to visualise the operation and results of the simulation effort. It offers insight in the BHS' behaviour.

In order to represent the BHSs in the right way, the engineers have to be enabled to simulate the BHS components as applied in the BHS solutions as designed by Vanderlande Industries. Therefor, all these components are documented, including their functionality (see appendix G). Building a simulation model during the sales phase, requires system representations on a level of abstraction, which is global enough to prevent the engineers (and customers) from getting lost in details and detailed enough to design valuable system concepts. To reduce complexity, details of the components are omitted which do not contribute to the insight in the systems behaviour. Based on their functionality, the components are grouped in so-called object classes. The object description technique means the definition of objects by identifying their attributes and

actions [Bots, et al, 1997]. The objects (the "building blocks" for the simulation model) represent a part of the BHS and together they form the total system. Appendix H shows the object model, which contains all required building blocks. They are grouped in the classes Input, Transport, Process, Sort, Output, Controls and Employees.

5.4.6 Cost breakdown structure

In the literature a difference is made between the costs involved with a system during its life cycle from the customer's point of view and from the producer's point of view [Ludema, Roos, 1998]. In this thesis, the costs included in the cost analysis refer to the Costs of Ownership, being the costs from the customer's point of view. In order to support the engineers in the cost analysis activity, the breakdown structure as shown in figure 5.5 is used to allocate different cost aspects of a BHS. It is meant to be a convenient framework upon which further details can be introduced.

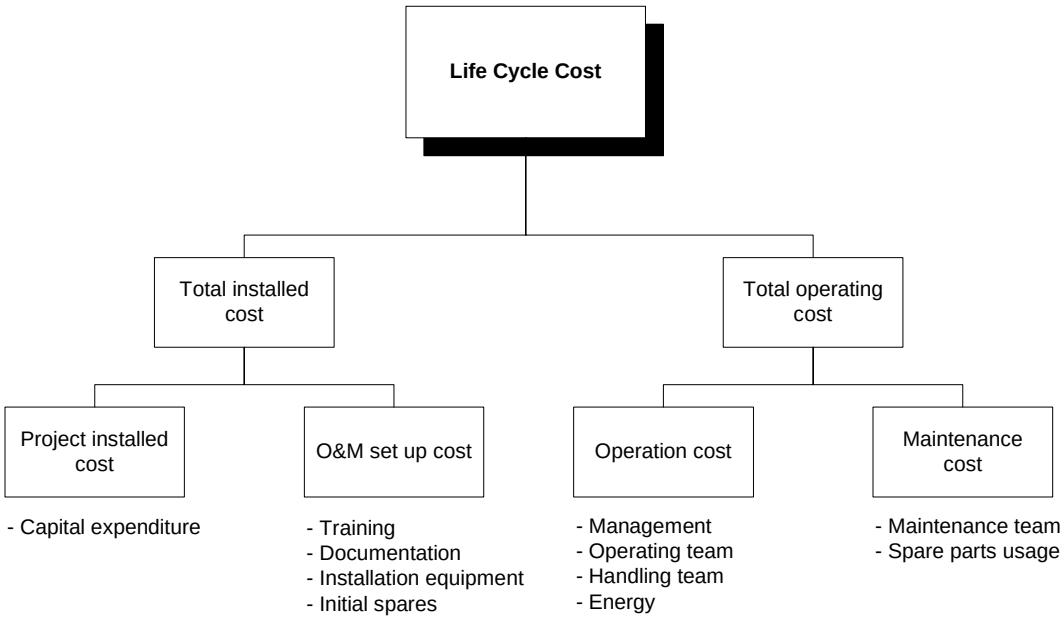


Figure 5.5 Life Cycle Cost breakdown structure.

These elements are based on the elements as mentioned in the Cost Breakdown Structure of Blanchard (see figure appendix F). Since this breakdown structure is too detailed to implement at Vanderlande Industries to introduce the "Life Cycle Cost design thought" (the start has to be simple and conveniently arranged), elements are omitted or joined. The following demarcation for the cost calculator came into being while consulting engineers of different departments (Proposal Verification & Pricing, Maintenance, Service International, Simulation and Systems Development). As mentioned above, for now only the costs from the owner's point of view are included. This means that the development and production costs are not considered separately, but are grouped in the capital expenditures of the customer. Although the actual costs are made by

Vanderlande Industries, the customer eventually pays for them in the form of the initial purchase investment (capital investment). And because of the relative importance of that initial investment to the customer, the cost elements are grouped in two periods of the systems life cycle. The first period ends when the BHS is installed, tested and, including the personnel, ready for operation (this moment is called the hand-over and the cost which are made up to then are the total installed cost). The second period starts right after the first one and ends the moment the BHS is no longer operational (the cost made in this period are the total operating cost). The costs of training the maintenance personnel e.g., although necessary for the maintenance activities during operation, are included in the set up costs. But the spare parts they use when the system is in operation are included in the maintenance costs.

Another demarcation is the omission of the system phase-out and disposal cost. Although the replacement of an old system plays a significant role, while in most cases there are requirements considering the operational continuation [Putten, van, 1999], there is a complete lack of data in relation to the complete life cycle cost. The use of space is also left out, although space is very expensive on the airport site. According to the experienced engineers the space is in most cases already reserved for the BHS the moment Vanderlande Industries receives the call for tender. Mainly in countries with humid heat, when an air conditioning is required, the cubic metres of space are relevant. Accept for this remark this aspect is not taken into further consideration.

The following financial aspects are, in consultation with the involved engineers, also excluded in this “cost calculator start-up structure”:

- Interest
- Inflation (the value of money has to be discounted for the time)
- Learning curves (experience in a certain application field could result in less cost in the remaining years of use)

5.5 Summary

In order to structure the compound solution to the defined problems, a new design methodology is developed. It came into being by interviewing employees and consulting literature on the defined problem areas. This methodology, that must help Vanderlande Industries to reach the stated objective, can be visualised by the table 5.5.

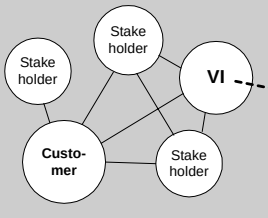
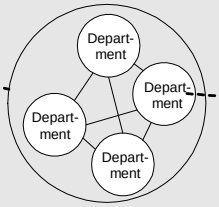
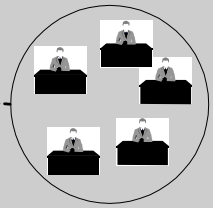
	Macro	**Meso**	**Micro**
	 Cooperation of organisations	 Coordination of processes between VI departments	 Primary tasks at workplace level
Way of thinking	"Getting grip on the decision process of the customer"	"Teamwork regarding evaluation and information processing"	"Integral justification including documentation of design choices"
Way of working	- Lobby - Stakeholders analysis - Requirements analysis - Feedback elicitation	- Team formation - Team based evaluation	- BHS design choices justification & documentation - BHS dynamic behaviour analysis - BHS cost analysis
Way of controlling	Process manager Commitment Drop out prevention Support Responsibilities division & documentation		
Way of modelling	Stakeholders analysis template Requirements analysis template	BHS concept design choices justification	BHS concept description template Simulation model Cost breakdown structure

Table 5.5 The new design methodology for the BHS sales phase.

6 Supporting tools

In the previous chapter, the new design methodology is described. Within this methodology new activities and models (intermediary products) are to be introduced in the BHS sales phase at Vanderlande Industries. In order to support the employees of Vanderlande Industries in performing these activities, automated tools are developed or existing tools "of the shelf" are evaluated for use in the sales phase. In the first section, 6.1, the general requirements on the supporting tools will be described. In section 6.2 the developed design choices justification tool will be illuminated, which supports the stakeholders and requirements analysis, the team based evaluations and the documentation of BHS concepts and their design justification. Section 6.3 describes the evaluated simulation package Enterprise Dynamics that supports the analysis of the dynamic behaviour of BHS concepts. The final section, 6.4, deals with the developed cost calculator that supports the engineers in performing a cost analysis.

6.1 Requirements on the supporting tools

While performing the new or adjusted design activities, the employees can be supported by new tools. The general requirements on these tools are described in this section. First of all there are some requirements given, which were found in the literature and apply to supporting tools according the Business Engineering design perspective. According to Mayer, the most powerful tool supports integration of the information in the different methods, supports automatic drawing of the graphical display of a view and supports the generation of quantitative analysis results or process implementations directly from the methods [Mayer, 2001]. This leads to the following requirements that also apply to the tools in this thesis:

- Enable efficient and effective knowledge capture
- Use graphical representations for clarification of communication
- Maintain a common, reusable repository (data / models source)
- Support team collaboration
- Enforce the correct application of methodology and methods
- Maintain a capability to export to other software tools
- Maintain an "enter once, use often" approach in data collection
- Ensure legitimacy of the tool (the user must understand and appreciate the tool content, application and handling)

In addition to these requirements, the following wishes were made known during the interviews and came into being while the project progressed:

- Logical and transparent structure
- Clear user interface (easy to use, also by inexperienced engineers)
- Extendable (adjustment to dynamic environment must be possible)

- Ensure security of the data that can be of use to the competitor(s)
- Ensure the tools to keep up to date

Besides these requirements on the tools in general, specific requirements apply to the different tools. Each of the following sections starts with a sub-section to describe these specific requirements.

6.2 Design choices justification tool

The design choices justification tool supports the following activities of the new design methodology:

- Stakeholders analysis
- Requirements analysis
- Team based evaluation
- Documentation of BHS concepts, including justification of the design choices

First, the specific requirements on this tool are described. In sub-section 6.2.2 the tool is described.

6.2.1 Requirements on the design choices justification tool

The tool is based on the templates and relations as shown in figure 5.4. Therefor the templates for the stakeholders and requirements analysis and the template for the documentation of a BHS concept are integrated in the tool. The tool must stimulate the Vanderlande Industries employees to integrate the “process” side of the complex sales phase with the “content” side. It must form a guideline for the exploration of the behaviour, strategy and position of different stakeholders in a complex environment. Regarding the requirements analysis, it has to be applicable for all possible BHS systems. It must be a comprehensive checklist to ensure completeness of the requirements. Besides, all requirements must be grouped in their proper context. Regarding the documentation of a BHS concept, the tool must stimulate the Vanderlande Industries Sales and Systems engineers to define the design choices they made in a clear and complete way, including the foundation.

Next to the general requirements as mentioned in section 6.1, additional requirements are introduced when assigning the main features of Requirements Management to the justification tool. According to Young a sophisticated requirements tool is able to facilitate requirements elicitation, help with prioritising of requirements, provide traceability of requirements throughout the development effort and allow for assignment of requirements to sub-sequence releases of system products [Young, 2001]. These requirements are also captured in the management requirement tool evaluation criteria used by the International Council on Systems Engineering [INCOSE, 2000], being the possibility to:

- Identifying, prioritising and (hierarchically) grouping the requirements

- Keeping up the history of the changes of the requirements
- Seeking certain sets of requirements (bi-directional, from the requirements towards the systems concept and v.v.)
- Supporting group wise usage (security, base lining)
- Viewing the relations between requirements and system concepts in both text and graphical way
- Visualising the differences between two versions of requirement sets
- Generating of reports
- Performing a validation by checking whether all requirements are consistently related to the concept
- Proving the concept is compliant with the requirements

6.2.2 Description design choices justification tool

This subsection describes the BHS design choices justification tool by highlighting the basic layout, function and content. For more details is referred to appendix E, which contains the total layout of the tool.

As mentioned before, the justification tool depends on three templates:

- The stakeholders template (model used when analysing the stakeholders network)
- The requirements template (model used when analysing the total set of requirements)
- The BHS concept template (used when documenting the BHS concept)

Because of the relations between these three templates they are integrated in one tool. It is based on a MicroSoft Excel-document, first of all to keep the barrier to use the tool low (every Vanderlande Industries engineer works with MS Excel often). Secondly, in the current situation Excel is already used to process and document quantitative results regarding cost and performance of a BHS. The tool can be stored and maintained on the IT Public Library (Vanderlande Industries network) and loaded for each project in VI_Projects to make it accessible for all concerning employees. VI_Projects is the central storage on the Vanderlande Industries Intranet of project related work documents.

Figure 6.1 shows the tool in MS Excel (the complete layout is shown in appendix E). It shows the worksheet named “general” that contains information like the project name and number, the customer’s organisation name and a revision table with the author’s name, date and reason for revision. Right below the objective of the justification tool, figure 5.4 is integrated in the tool, to explain the relations between the worksheets. The templates (consistent with the terminology of Excel called worksheets) named “stakeholders”, “requirements” and “concept” can be found at the bottom of figure 6.1. To make it possible to integrate more than one BHS concept, there are two copies of the concept worksheet added to the tool. The latest worksheet, named “concept history”, is added to document the history of concepts.

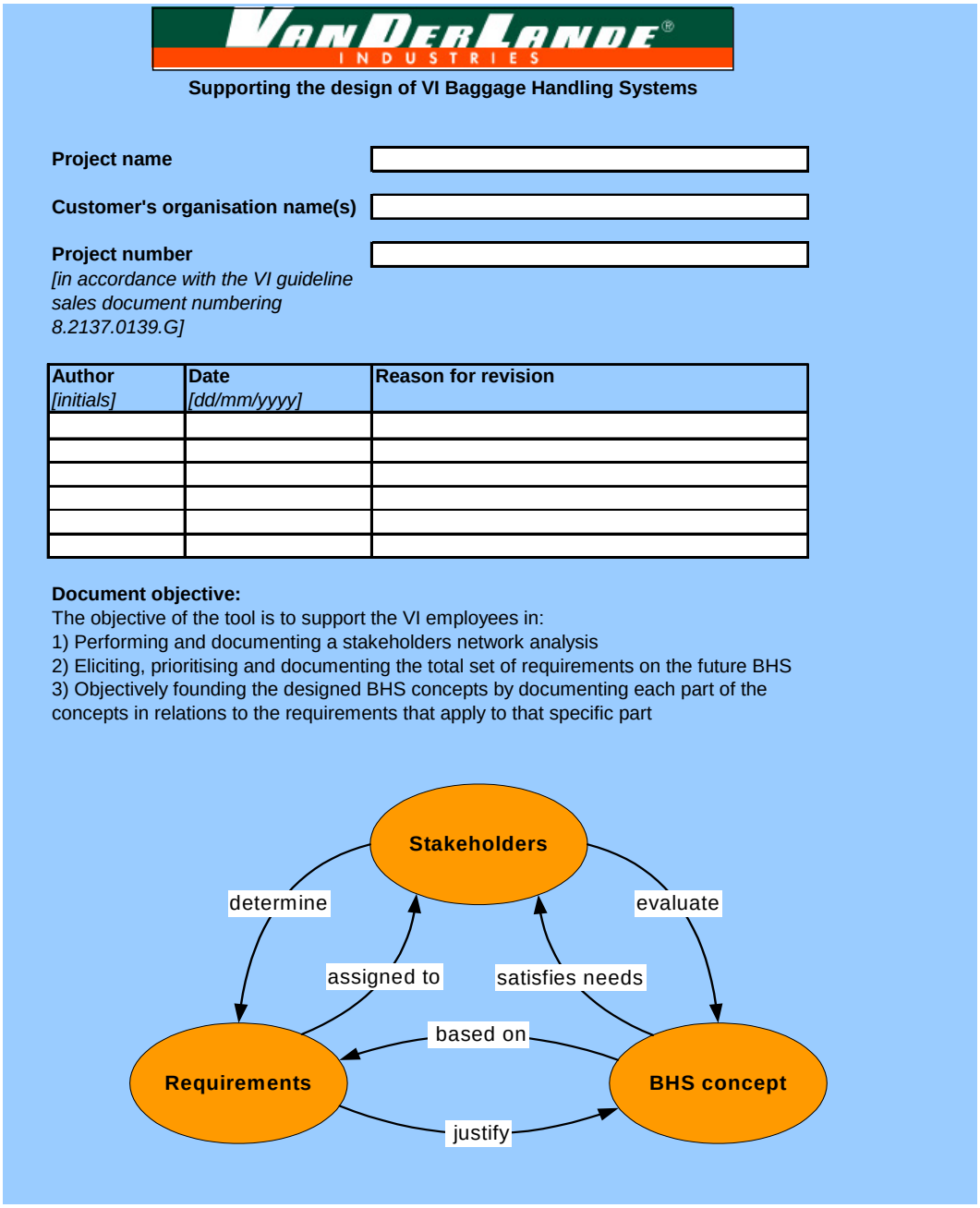

VAN DER LANDE INDUSTRIES
Supporting the design of VI Baggage Handling Systems
Project name
Customer's organisation name(s)
Project number
[in accordance with the VI guideline sales document numbering 8.2137.0139.G]
Author [initials]
Date [dd/mm/yyyy]
Reason for revision
Document objective:
The objective of the tool is to support the VI employees in:
1) Performing and documenting a stakeholders network analysis
2) Eliciting, prioritising and documenting the total set of requirements on the future BHS
3) Objectively founding the designed BHS concepts by documenting each part of the concepts in relations to the requirements that apply to that specific part
Stakeholders
determine
evaluate
assigned to
satisfies needs
based on
Requirements
BHS concept
justify

Figure 6.1 The general worksheet in the justification tool.

Stakeholders worksheet

The stakeholders worksheet contains edit fields for the items of the template for the stakeholder network analysis, as described in sub-section 5.4.1. It guides the engineers and sales men in documenting all relevant stakeholders who can have an influence on how the quality of a BHS is experienced. By taking all wishes and requirements into consideration, a better weighing of pro's and con's of BHS concepts can be made (and no important factors are omitted). Filling of the worksheet will be performed iterative, because in the initial contact phase, not all the information is available yet. Each item is

provided with hint text (see example figure 6.2) to support the filling of the template (for more details is referred to appendix E).

3 Stakeholders

[Not only those stakeholders that are intentionally selected and activated and thus more closely involved in the design process, but also the indirect involved stakeholders, who can play an important role (such as blocking or promoting a solution). Think of:
Airport authorities
Airport employees (levels: management, operations, maintenance, contracting, finance, etc.)
Airport operators
Main contractors
Consultants
Airlines
Architects
Project managers (external)
Handling agent (independent party with core business baggage handling, e.g. OGDEN)
Competitors
Agents working for VI or other stakeholders
Partners (mostly Controls)
Sub-contractors
Security stakeholder
Shop owners
Government (different levels, EU, National, District, Local)
Passengers
Media
Commercial organisations with influence (for instance large customer of airport).
Agents
VI colleagues (management, Salesmen, Area managers, Sales engineers, Systems engineers, Simulation engineers, CAD engineers, Controls engineers, Contracting, Mechanical engineers, R&D engineers, VI project manager, Purchasing, Planning, Pricing, Customer Centres)
Etc.]

ID (initals)	Organisation name	Department	Person	Function	Telephone & e-mail
[initials]	*[name]*	*[department name]*	*[person's name]*	*[function name]*	*[telephonenr. & e-mailaddress*
MF	FlyHappy Airport	Operations	Mike Flight	Manager Operations	Flight@FlyHap.com

Figure 6.2 The stakeholders identification input table.

Requirements worksheet

The requirements worksheet guides the involved Vanderlande Industries employees in documenting the total set of requirements and constraints that apply to the concerning project. Similar to the introduced template for requirements documentation, the worksheet is divided in five parts: introduction, general functionality and technology requirements, constraints, specific BHS requirements and procedural requirements.

In figure 6.3 an example is shown of a documented functionality requirement. Each requirement has attributes such as author initials and priorities to link the requirements with the stakeholders of the previous worksheet and to prioritise them. The initials of the author and ID code of the requirement help tracing the requirement through the project. The prioritisation of the requirements before spending resources on them, offers greater flexibility in tradeoffs, design and implementation [Hooks, Farry, 2001]. In the example engineer BB has record a requirement, assigned to MF. MF has stated that this requirement is mandatory in the BHS concept. The priority of Vanderlande Industries regarding this requirement is high (result of the team based evaluations).

2 General functionality and technology requirements

[Keep the entered requirements in accordance with the characteristics mentioned in the introduction]

2.1 Check-In functionality and technology

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Check-in functionality required? If yes, certain technology required?]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yyyy]*	*[further details and possible changes]*
BB	FT1.1	Walk-through check-in desks including elevators	MF	Mandatory	High	16-5-2002	MF saw walk-through check-in on Köln-Bonn Airport
	FT1.2						
	FT1.3						
	FT1.4						
	FT1.5						

Figure 6.3 Check-In functionality and technology requirements input table.

Concept worksheet

The concept worksheet contains, again similar with the template described in the way of modelling, the concept layout, the technology specification, the cost effectiveness and possible references. Each item is provided with an input table to specify the designed concept concerning that item, including author initials and comments (see upper table in figure 6.4).

2 Technology specification

2.1 Check-in technology

Author	Technology	Comments
[initials]	*[specification of the applied check-in technology]*	*[Comments regarding the check-in technology]*
BB	50 walk-through check-in desks, combined with 25 elevators (type X1200 from subcontractor TD)	Stainless steel covers. Weighing belts included.

[Requirements and/or constraints concerning the check-in technology]

Requirem. / constr.	Description	Compliance level	VI Priority	Assigned to	Organsiation	Person
[ID code]	*[Requirement / constraint description*	*Mandatory / guidance*	*High / medium / low*	*[initials]*	*[Organisation name]*	*[Person name]*
FT1.1	Walk-through check-in desks	Mandatory	High	MF	FlyHappy Airport	Mike Flight
FT1.2	0	0	0	0	#N/A	#N/A
FT1.3	0	0	0	0	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Figure 6.4 Check-in technology specification and justification table.

In the left white column of the lower table figure 6.4 the engineer can fill in the ID codes of the requirements and constraints that apply to this BHS item. The tool than automatically displays the corresponding requirement/constraint description, the compliance level, the Vanderlande Industries priority, the initials of the source of the requirement or constraint and the name of the corresponding organisation and person. These are obtained from the Stakeholder and Requirements worksheets. There are some default requirement and constraint codes entered in the tables because the relation between the concerning BHS item and the requirement or constraints is fixed. In addition to these defaults the engineer must enter all other relevant codes, on which the design

choices are based. Based on the combination of applied BHS items and BHS configuration with the concerning requirements and constraints, the engineer can individually or together with colleagues evaluate the designed BHS concept.

6.3 Simulation tool

To make a discrete event simulation model, a simulation software package is required. Installed on a PC this forms the simulation tool that supports the analysis of the dynamic behaviour of a BHS concept. After the description of the requirement on such a tool in sub-section 6.3.1, the tool is described in sub-section 6.3.2.

6.3.1 Requirements on the simulation tool

Besides the general requirements as mentioned in section 6.1, interviewing several Sales and Systems engineers revealed additional, more specific requirements on the simulation tool. The following system performance output requirements for the simulation tool came up:

1. Maximum throughput (distinguished in transfer, terminating and originating baggage flows)
2. Utilisation measure of the resources
3. In-system-times (travel times) of the bags

It must be possible to produce these quantitative output results for different scenarios (variance of bag arrivals, flight schedules or configuration) and different availability of resources (redundancy tests). Besides the quantitative system performance the engineers also require insight in the system behaviour to identify bottlenecks.

The engineer must be able to compare different BHS concepts, based on the performance output as mentioned above. The concepts can differ in:

- Locations of the BHS processes (processes described in section 1.2)
- Connections (and therefor the sequence) between these BHS processes
- Technology used for these BHS processes and connections (technology described in section 1.2)

In order to represent the BHSs in the right way, it must be possible to simulate the BHS objects (BHS components) of appendix H.

6.3.2 Description simulation tool

The engineers of the Simulation Group of Vanderlande Industries had put their mind on a simulation software package, next to AutoMod, to enable the simulation engineers to quickly build simulation models with less detail than the AutoMod models. Therefor, a license for special-purpose (material handling) discrete simulation software is purchased, named Enterprise Dynamics (ED). Within this ED simulation environment, a simulation

model can be build by placing predefined building blocks (objects) in a layout. To decrease the time necessary for simulating a BHS, several building blocks specially tailored for baggage handling are added to the standard logistic objects integrated in ED. These BHS building blocks (e.g. a tilt-tray sorter, a carousel, a security screening machine, etc.) are grouped in a repository, named the ED BAXSIM library. In appendix I the possibilities of the simulation package ED are described in more detail. The description of the objects integrated in the BAXSIM library can be found in section I.10 of the appendix I.

When a model layout is determined by dragging all required equipment into the model with the right physical dimensions, the engineer can connect the equipment in the baggage flow sequence (for details is referred to the Enterprise Dynamics User Manual). Via menus the input parameters can be set, without actual programming. Figure 6.5 shows the screen layout of ED while running a simple model. At the left side the “library tree window”, in which the building blocks are listed. In the model layout some simplified BHS equipment is shown (check-in, conveyors and a carousel), including their connections.

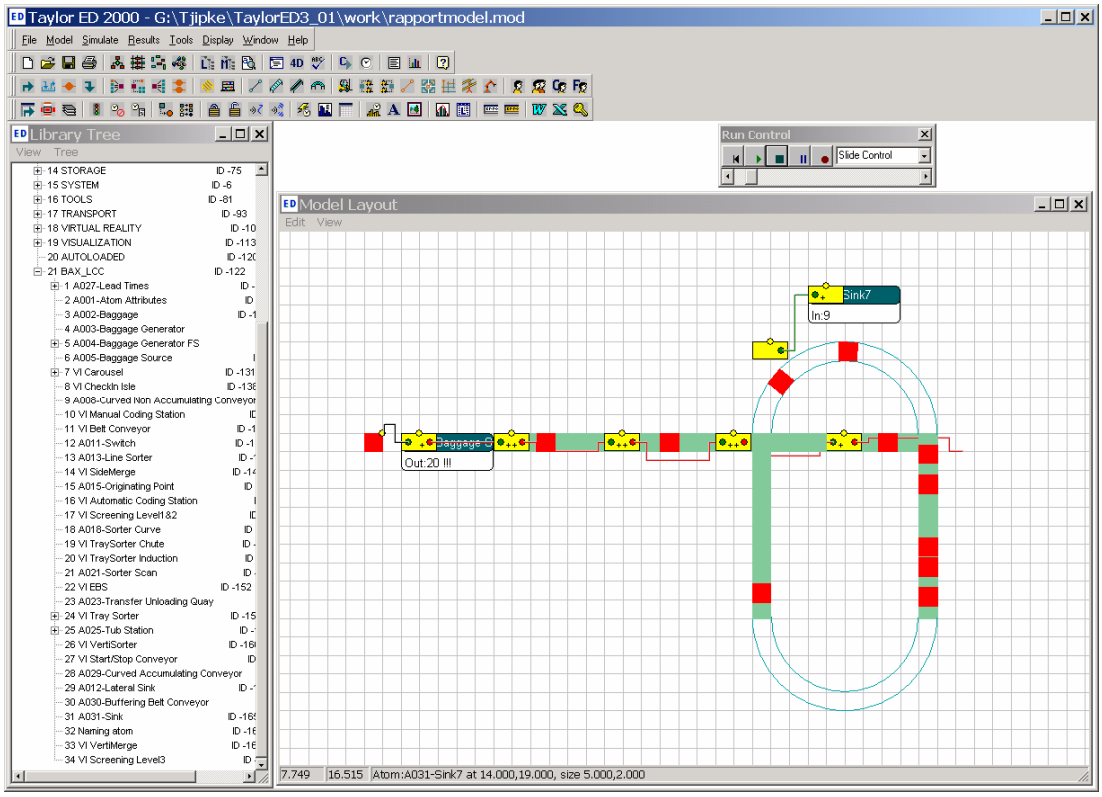


Figure 6.5 2D model layout, library tree and run control window within the ED window.

When the 2D model layout is created, the simulation package automatically generates a 3D model layout. This supports the engineer in presenting the model to other people and validating the configuration and logic. Figure 6.6 shows the 3D representation of the simulation model of figure 6.5.

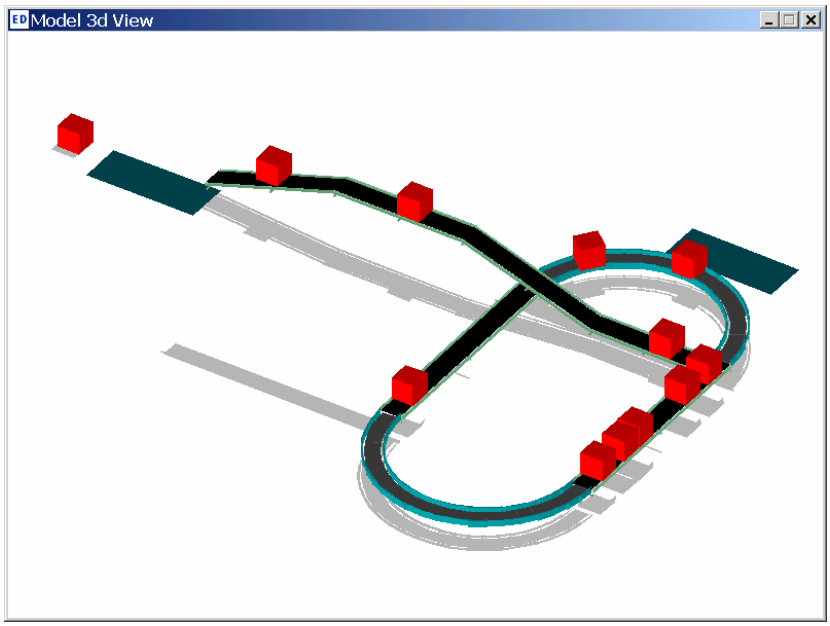


Figure 6.6 3D model layout window.

During the actual runs, ED offers the possibility to vary the speed of the simulation or to stop for a moment and continue for instance step by step. The output of a simulation run can be stored within the simulation model or can automatically be exported to MS Excel or a database. ED is also provided with monitoring possibilities, which enable the engineer to survey specific performances during the run. Existing models, or parts of existing models, can in most cases be reused when building new models of other alternatives.

Summarising, the ED simulation tool is a graphical oriented simulation package based on objects with attributes and (inherited) behaviour. By dragging the required objects into a model layout, connecting them and defining the input parameters via menus it is easy to build a simulation model. Its reverse is the restricted level of detail of the model when no actual programming is applied. By adding code the behaviour and the menu interface of the objects can be extended to get more detail. The animation in both simplified 2D and more detailed 3D makes analysis of bottlenecks, flows, queues and equipment utilisation possible. The performance results can be visualised during the simulation or can be exported to other software.

6.4 Cost calculator

To support the cost analysis activity of the new design methodology, a cost calculator is developed. This section also is divided in the requirements on the tool (6.4.1) and the description of the tool (6.4.2).

6.4.1 Requirements on the cost calculator

The following characteristics are required for the cost calculator:

- Easy to use (by both experienced and inexperienced Sales and Systems engineers)
- Calculating the different cost elements should not take to much time
- Logical, transparent structure (to preserve the engineer from thoughtlessly following the calculation results)
- Extendable (the moment additional data is found and approved, it must be added to the tool)
- Security of confidential information
- Information must be kept up-to-date
- Engineers must be able to document the results easily

The information that must be delivered by the calculator must contain:

- Rough cost amounts (elements as mentioned in the cost breakdown structure of figure 5.5) in order to compare BHS concepts (relative) and to estimate the impact of a certain change within a concept (absolute).
- A graph that represents the total cost of the system per year of the life cycle

6.4.2 Description cost calculator

To keep the calculation of the costs easy and quick, work performed in the previous stage of the design process is reused, namely the simulation model of the BHS. This way, for calculation the engineer does not have to re-enter all the systems characteristics such as the number, length and speed of the conveyors, the number and level of screening machines, the type of sorting equipment, etc. So the developed calculator, is based on the objects concept of Enterprise Dynamics and can be loaded in the ED objects library (the left column in the screen dump of figure 6.5). The calculator is based on a base class (empty) object integrated in the ED software. The attributes that were added are described in appendix J.

After (or during) the building of the simulation model of a certain BHS, the engineer can drag the cost calculator into the model layout window. The appearance of the cost calculator after dragging it into the window is shown in the screen dump in figure 6.7. In the blue left column the initial input parameters are displayed, the right column displays the output fields.

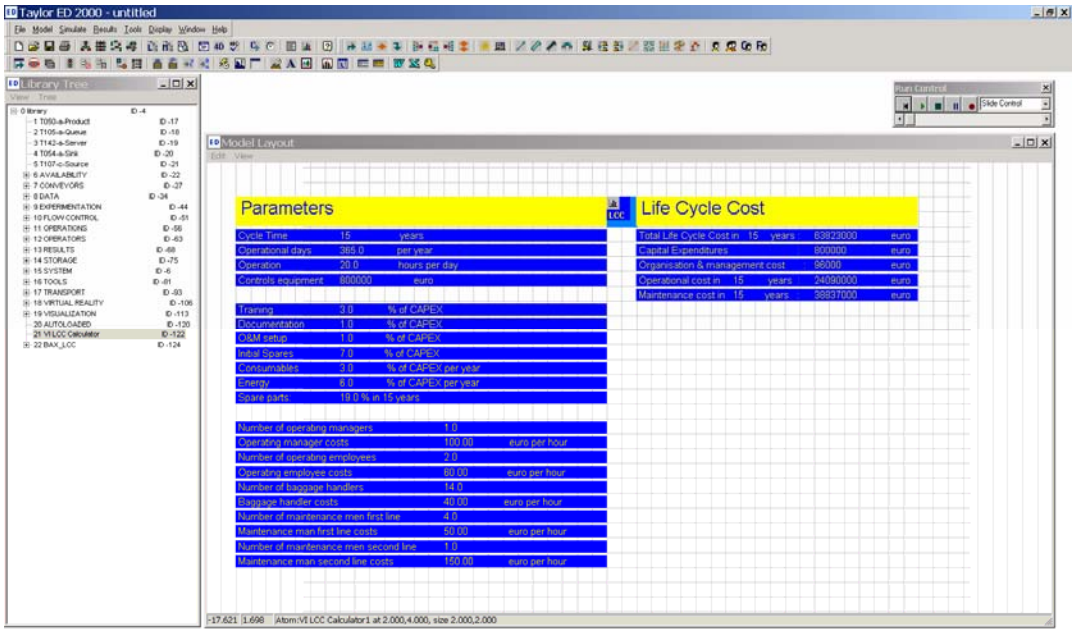

Taylor ED 2000 - untitled
Library Tree
Model Layout
Parameters
Life Cycle Cost
Cycle Time 15 years
Operational days 365.0 per year
Operation 20.0 hours per day
Controls equipment 800000 euro
Training 3.0 % of CAPEX
Documentation 1.0 % of CAPEX
O&M setup 1.0 % of CAPEX
Initial Spares 7.0 % of CAPEX
Consumables 3.0 % of CAPEX per year
Energy 8.0 % of CAPEX per year
Spare parts 19.0 % in 15 years
Number of operating managers 1.0
Operating manager costs 100.00 euro per hour
Number of operating employees 2.0
Operating employee costs 80.00 euro per hour
Number of baggage handlers 14.0
Baggage handler costs 40.00 euro per hour
Number of maintenance men first line 4.0
Maintenance man first line costs 50.00 euro per hour
Number of maintenance men second line 1.0
Maintenance man second line costs 150.00 euro per hour
Total Life Cycle Cost in 15 years 63923000 euro
Capital Expenditures 800000 euro
Organisation & management cost 96000 euro
Operational cost in 15 years 24090000 euro
Maintenance cost in 15 years 38837000 euro

Figure 6.7 Result after dragging the LCC calculator atom in the model layout window.

After the cost calculator is placed in the model layout window, the input parameters have to be entered. By double clicking on the LCC icon (between the columns) a menu opens with the following options: Capex, Organisation & Management set up, Operation and Maintenance. When clicking on one of these options, a submenu appears in which the engineer can enter the elements of the costs that will be included in the calculations. Figure 6.8 shows the submenu of the O&M set up cost. By checking the boxes the engineer can choose whether documentation, training, O&M equipment or the initial spares should be included.

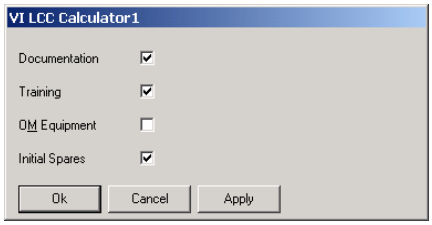
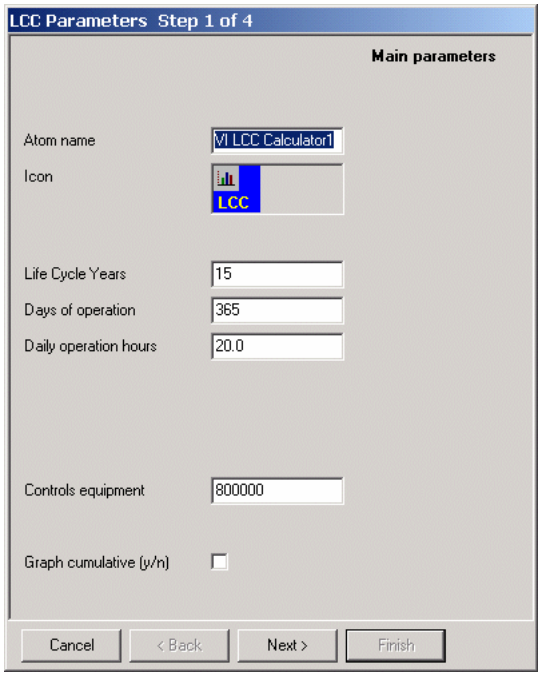


Figure 6.8 Choice window of the O&M set up which elements to include in the calculations.

After defining all elements to be included, the engineer can give a right mouse click on the LCC icon to start the input steps. The first step that appears is shown in figure 6.9. When the mouse cursor is placed above an edit field, a hint text appears to explain in more detail which parameter is entered. If the engineer enters values that are out of range, an error message will pop up and give the possible range. The allowed ranges are included in appendix J, describing the attributes of the calculator.



In this step the name of the calculator object and, if desirable, the icon can be changed. In the three edit fields in the middle the total time cycle of the system must be entered, depending on the number of years, the number of days per year and the number of hours per day the system will be operational. The edit field at the bottom contains the estimated price of the high-level system controls in euro's. If the checkbox below is check, the result will be visualised in a cumulative graph, instead of a bar graph. After all fields are filled as desired the engineer can click the next button in order to get to step 2, shown in figure 6.10.

Figure 6.9 First input step window on right mouse click.

In step 2 the elements which are calculated as a percentage of the capital expenditures are entered. The four upper edit fields concern the O&M setup cost and therefor concern cost that have to be made only once. The percentages for consumables and energy are added to the total cost each year of the life cycle (this is explained in the hint text that appears if the mouse cursor is placed above the edit field).

If the engineer is satisfied with the parameter values (or if the elements are not included in the calculation, see figure 6.8) clicking next will open the next step window which is shown in figure 6.11.

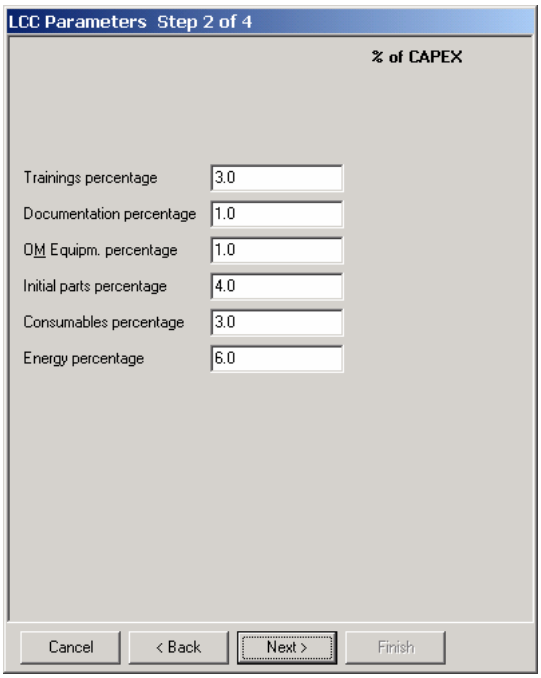
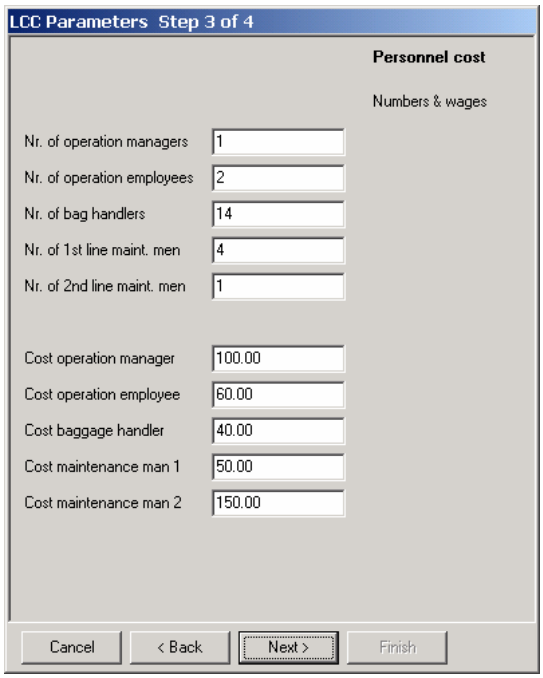


Figure 6.10 Second input step: capex percentages.

In this step, step 3, the parameters for the personnel cost calculation during the life cycle of the BHS are entered. Five functions are distinguished:



- Operations manager
- Operations employee (working in the control room of the BHS)
- Bag handlers (loading/unloading bags, manual coding, etc.)
- Maintenance man first line (non-complex maintenance such as oil replacements and visual checks)
- Maintenance man second line (more complicated maintenance, such as replacements and thorough quality inspections).

For each function the number of people necessary (depending on the BHS layout and technology) and their labour cost can be entered.

Figure 6.11 Third input step: personnel numbers and wages.

The last input step window, shown in figure 6.12, contains the percentages of capital expenditures for the spare parts necessary. Some components of the BHS have to be reconditioned, or even completely replaced, after a certain number of operational hours. In this input step the engineer can make estimations of the spare parts cost for each year. The life cycle of the system is limited to 30 years in step 1, so step 4 offers a maximum of 30 edit fields. After entering all necessary parameter values (review is possible by clicking on the back button) the engineer clicks on the finish button.

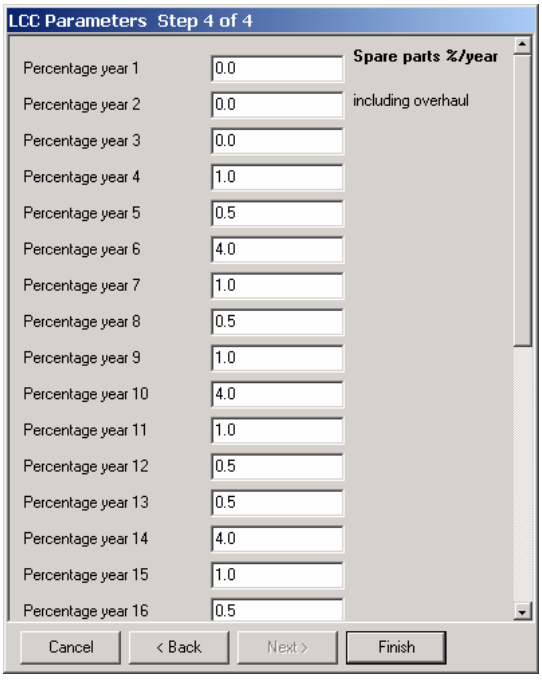
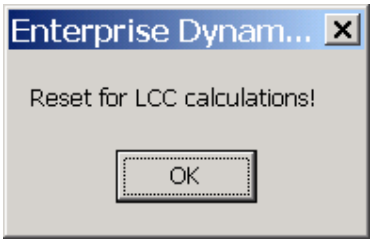


Figure 6.12 Fourth input step: Capex percentages.



After clicking the finish button the message as shown in figure 6.13 is displayed to remind the engineer that the calculation is only performed after resetting the model.

Figure 6.13 Reminder message after the last input step.

After the model reset, the cost calculations are made and the results are displayed as shown in figure 6.14. On the left side, the input parameters are displayed which were entered in the four steps as mentioned before. In the upper row of the blue column on the right the total costs of the BHS as represented in the simulation model are given. The total costs are calculated by adding the four amounts right below the total amount (these are the four main elements Capital Expenditures, Organisation & Management costs, Operational costs and Maintenance costs as distinguished in the cost breakdown structure of figure 5.5).

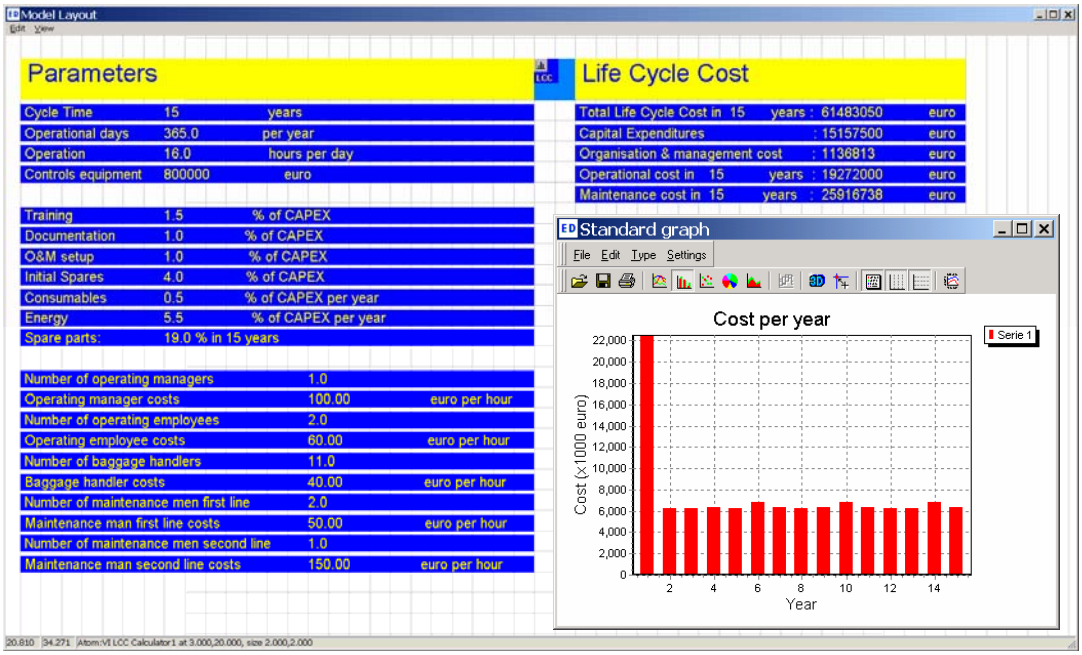

Model Layout
Parameters
Life Cycle Cost
Cycle Time 15 years
Operational days 365.0 per year
Operation 16.0 hours per day
Controls equipment 800000 euro
Total Life Cycle Cost in 15 years : 61483050 euro
Capital Expenditures : 15157500 euro
Organisation & management cost : 1136813 euro
Operational cost in 15 years : 19272000 euro
Maintenance cost in 15 years : 25916738 euro
Training 1.5 % of CAPEX
Documentation 1.0 % of CAPEX
O&M setup 1.0 % of CAPEX
Initial Spares 4.0 % of CAPEX
Consumables 0.5 % of CAPEX per year
Energy 5.5 % of CAPEX per year
Spare parts: 19.0 % in 15 years
Number of operating managers 1.0
Operating manager costs 100.00 euro per hour
Number of operating employees 2.0
Operating employee costs 60.00 euro per hour
Number of baggage handlers 11.0
Baggage handler costs 40.00 euro per hour
Number of maintenance men first line 2.0
Maintenance man first line costs 50.00 euro per hour
Number of maintenance men second line 1.0
Maintenance man second line costs 150.00 euro per hour
Standard graph
File Edit Type Settings
Cost per year
Serie 1
Cost (x1000 euro)
Year

Figure 6.14 The input and output results after reset.

The graph that appears contains the cost the customer (or Vanderlande Industries, depending on the contract) will have to face in the life cycle years of the BHS. In the first year logically the cost are the highest. In this year the customer has to invest in the system components, installation, training, documentation, initial spares, etc. The years after contain both fixed cost (such as the consumables and personnel cost) and variable cost (the spare parts including overhaul). The results in the graph can be documented easily by clicking the edit button in the graph window and then choosing between copying the data or the graph bitmap itself. The results can be pasted in other applications such as MS Excel (and therefor in the BHS concept justification tool, introduced in section 6.2). If the engineer had chosen a cumulative graph in the first step of the input menu, a graph as shown in figure 6.15 appears.

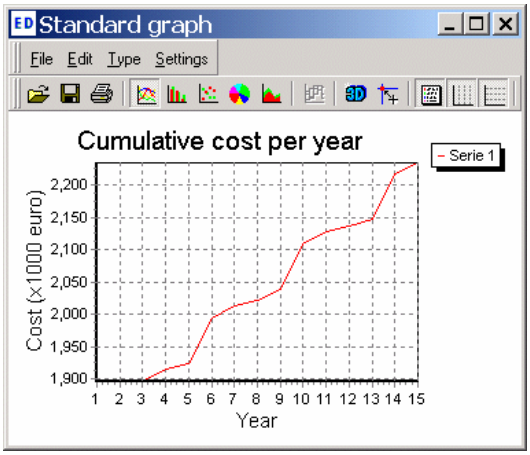


Figure 6.15 The calculation results represented by a cumulative cost graph.

The cost calculator makes it very easy to zoom in on different life cycle cost elements and to communicate the results with others. For instance, if only the spare parts are considered, the rest of the elements are excluded by not checking the boxes in the submenus that pop up by double clicking the LCC icon. After resetting the model the graph as shown in figure 6.16 pops up. It displays the costs that are to be expected for each year for spare parts only.

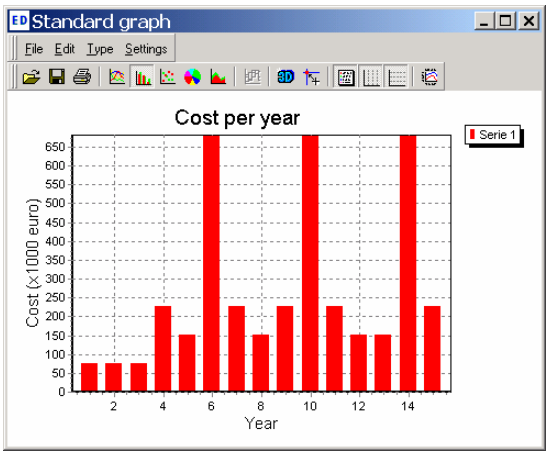


Figure 6.16 The calculation results represented by a bar graph, if only the spare parts are considered.

Now that the interface is known, the content (calculation methods) of the cost calculator must be found. As mentioned before, there is hardly any data available concerning life cycle costs of BHSs. Therefor rough, guiding estimations are made that need to be detailed in the near future. The following three estimation methods are distinguished [Blanchard, Verma, Peterson, 1995] and applied:

- Method A: Finding the total cost by multiplying the incremental unit cost by the quantity of units involved
- Method B: Finding some higher level of relationships such as non-linear or multivariate relationships
- Method C: Cost estimation by expert opinion (the experts in this thesis were Vanderlande Industries engineers from Pricing, Maintenance, Simulation and Concepting)

The estimated results considering the cost elements that are distinguished in the cost breakdown structure can be divided in three groups of estimation accuracy. The first group of costs, are the capital expenditures (capex, costs of a completely installed BHS including high-level controls). These costs can be estimated in adequately accuracy, by using estimation methods A, B and C. The second group, the personnel cost, depend on the country and environment in which the BHS will operate and will therefor be estimated for each situation separately. For the third group, the rest of the elements, there is hardly any data available. In consultation with the experts (Vanderlande Industries engineers) these cost elements are calculated as a percentage of the capex, which can be modified in the input menu steps, as mentioned earlier. The cost calculator content can be adjusted or extended if new data is found.

The moment the engineer clicks the reset button, the cost calculator takes several calculation steps (appendix K contains a diagram that represents these steps). In a loop function the calculator finds all BHS components (objects) present in the simulation model and adds their components based capex to the total capex amount. Because of the relevance of the capex (several elements are given as a percentage of the capex) the calculation of these capex formed the centre of attention. An internal table of the cost calculator is used as the base of the capex calculation. Appendix L describes this table, including the way the calculations are made. Advantage of using one table in the cost calculator, instead of storing the capex data in each BHS component separately, is the easy finding and entry of the data if, for instance for inflation correction, several values have to be modified.

As mentioned the calculator finds all BHS components in a loop. It must identify the component and in some cases obtain some additional attribute values in order to calculate the capex of the concerning component. Therefor, the components (objects) of the BAXSIM Suite are adjusted to make them suitable for the cost calculator. Appendix M describes these adjustments per object.

The moment the capital expenditures are calculated, the other cost elements can be estimated. The labour costs are simply calculated by multiplying the number of operational hours with the hourly cost per employee. The other elements are estimations based on a percentage of the total capital expenditures on the system. During talking to engineers about the life cycle cost of a BHS some remarks and estimations were made concerning the percentages. These estimations can be guiding but should be verified before applying in a certain situation. These estimations are given in appendix N.

6.5 Maintenance of supporting tools

The tools as mentioned in the previous sections have to be stored at one central, accessible place such as VI_Projects on the internal network, to ensure the users to work with the latest versions. The responsibility for the maintenance of the design choices justification tool (completeness and correctness of the templates) can be allocated at the

Knowledge Management team (part of the Systems Group). This requires feedback on the usefulness of the templates in real practise and ongoing improvement.

Maintenance of the tools to support the simulation and cost analysis also is the responsibility of the Systems Group (Knowledge Management, Simulation and Proposal Verification & Pricing). Regarding the simulation tool and the user interface of the cost calculator, two simulation engineers should integrated updates and gather feedback about the usefulness. The content of the cost calculator should be guarded by a pricing engineer in consultation with a Knowledge Management team member.

6.6 Summary

During the development of the new design methodology, development and/or evaluation of supporting tools were integrated. Three tools, based on in participation stated requirements, are introduced to support the employees of Vanderlande Industries in the BHS sales phase: the design choices justification tool (developed), the simulation tool (existing) and the cost calculator (developed). Table 6.1 shows the relation between the developed methodology and the introduced tools.

	Macro Cooperation of organisations	**Meso** Coordination of processes between VI departments	**Micro** Primary tasks at workplace level
Way of thinking	"Getting grip on the decision process of the customer"	"Teamwork regarding evaluation and information processing"	"Integral justification including documentation of design choices"
Way of working	- Lobby - Stakeholders analysis - Requirements analysis - Feedback elicitation	- Team formation - Team based evaluation	- BHS design choices justification & documentation - BHS dynamic behaviour analysis - BHS cost analysis
Way of controlling	Process manager Commitment Drop out prevention Support Responsibilities division & documentation		
Way of modelling	Stakeholders analysis template Requirements analysis template	BHS concept design choices justification	BHS concept description template Simulation model Cost breakdown structure
Supporting tools	Design choices justification tool		Simulation tool Cost calculator

Table 6.1 The new design methodology including supporting tools.

The design choices justification tool is a MS Excel document that offers templates for supporting and documentation the stakeholders analysis and the requirements analysis.

Besides, it includes a template to support the making and documentation of design choices regarding a BHS concept. In addition to that, it offers insight in the relations between the stakeholders, the requirements and the design choices that are made.

The simulation tool is a existing graphical oriented simulation software package of Enterprise Dynamics (ED), including the so-called BAXSIM library containing objects, tailored to baggage handling systems. It supports the Sales and Systems engineer to determine the (quantified) performance of a BHS concept on a rather high level of abstraction. It also offers insight in the dynamic behaviour of designed BHS concepts which enables the engineer to compare different alternatives.

The cost calculator is based on the same simulation package ED and supports the Sales and Systems engineer in making a quick, quite accurate estimation of the investment costs of a BHS concept. Besides, it offers the possibility to get a feeling of the other elements of life cycle costs of a BHS.

The Knowledge Management team of Vanderlande Industries will have the responsibility for maintaining the tools and making them available for the users.

7 Evaluation of methodology and tools

The new methodology and the supporting tools are the results of several interviews, discussions and literature research. To decide whether the results will contribute to reaching the desired situation (reaching the objective), some evaluation activities are performed, in cooperation with employees of Vanderlande Industries. The first section deals with the methods that were used during the evaluation. Section 7.2 describes the evaluation results for the new methodology. The following sections describe the evaluation results of the supporting tools, being the design choices justification tool (7.3), the simulation tool (7.4) and the cost calculator (7.5). The chapter is summarised in section 7.6.

7.1 Evaluation method

The new design methodology and the tools have not been applied in a real situation yet, mainly because the sales phase of a BHS can take several years while only limited time is available for this thesis project. Besides, the sales phase is very complex considering the number of involved stakeholders and factors of relevance, which makes it hard to test in a simulated situation. The new process makes the engineers aware of strategic behaviour of stakeholders but historical data about this "soft" aspect is not available. Therefor, the evaluation is separated in the methodology and the three tools and approached as described in the following sub-sections.

7.1.1 The new design methodology

The verification of the methodology was already performed during the development. In iterative steps, new elements or parts of the methodology were checked on realism and rationality. The evaluation considering the quality and viability of the methodology is based on the reactions of several experienced Vanderlande Industries employees when confronted with the new methodology (see appendix C). Some evaluation meetings were group wise (up to four attendants), some were individually. They work in different Customer Centres, different departments (disciplines) and different (management-) layers. Some of them were already involved in the development of the new design process. Others had nothing to do with the development up to then. Their remarks are grouped in remarks related with the way of thinking, working, controlling and modelling.

7.1.2 The supporting tools

The design choices justification tool is tested against the requirements as stated before in section 6.1 and 6.2.1. Besides, the tool is presented to the employees involved in the evaluation to gather their judgement whether the tool will help reaching the objective. On non-participating basis, the simulation tool is evaluated, based on criteria for simulation

software as stated by Nikoukaran [Nikoukaran, et al, 1999]. Besides, the tool is tested against the requirements as defined in chapter 6 on the simulation tool, which includes the making of three simulation models of different airports to judge the tool from an user point of view. The cost calculator in conclusion, is tested against the requirements as defined in chapter 6. A separate verification is performed and the validation exists of a replicative validation and an expert validation. A test case of a BHS is performed, to evaluate the calculator quantitatively in the replicative validation. In the expert validation employees are confronted with the tool and their judgement is recorded.

7.2 Evaluation of the design methodology

The evaluation results are grouped by the four ways of the methodology framework (see table 6.1). Sub-section 7.2.5 recapitulates the findings of this section.

7.2.1 Evaluation of the way of thinking

All interviewed employees recognised the urgency to spend more time on the decision process of the customer. It became clear that the factors such as personal preferences and relationships between different parties were of overriding importance in the decision making process of the customer about who should be awarded with the order. All employees agree on the statement that the new methodology will strengthen the professional appearance of Vanderlande Industries and that the chances to get awarded with a contract increase by broadening the knowledge with process aspects and therefor base the offered BHS design on a more complete set of requirements.

Regarding the coordination between different disciplines of the elicitation and evaluation of information, the formation of design teams working on specific projects was judged as a good change. The integral (quantitative) justification of the design choices made by the Sales and Systems engineers, was supported by all involved employees. Several employees stressed that the relevance of the quantification of the design choices justification should be determined for each project specifically. A good balance between the project time available and the time spend on the quantification must be found.

7.2.2 Evaluation of the way of working

The way of working regarding the communication of Vanderlande Industries employees with the stakeholders, including documentation of the results of this communication, is supported by all interviewed employees. They confirmed the need for a structured way of working including moments of evaluation and reflection on the designed concepts and the information they are based on. This was illustrated by described situations in which the involved people take a quick decision in an early stage of the project in order to start with the “real” design work as soon as possible. Later it appeared that the information the decision was based on, was out of date and crucial for the success of the offered concept.

The employees also support the team formation, including the documentation of the responsibilities. It will improve efficiency because the same work will not be done twice, everybody aims for the same objectives, there will be less iterations in the design process and the evaluation can be performed quicker and more structured. This will also improve the professional appearance of Vanderlande Industries because there will be no misunderstandings among VI employees and no double questions will be asked. Besides, the lobby, stakeholders and requirements analysis and the feedback activities will enable the employees of Vanderlande Industries to approach the right people at the right moment with the right arguments. They will also be able to link the right solutions to the right interests, etc.

The employees recognise that the quantified justification of the design choices will support the team evaluations. They are convinced that it offers salesmen and engineers persuasion power when presenting solutions. The analysis of dynamic behaviour and costs and the relations between the BHS concept and its environment offer the Sales or Systems engineer a wider insight to base their design decisions on.

7.2.3 Evaluation of the way of controlling

In this sub-section, several remarks regarding the controllability of the new methodology are given. First of all, now is the right moment to implement the new methodology because the management of Vanderlande Industries is aware of the introvert culture at Vanderlande Industries and is eager to change that. The cooperation of the management is also required because of their important role in the lobby activities. So not only horizontal communication is required, but also a good vertical communication within the Vanderlande Industries organisation in order to make the best out of the lobby activities. E.g., if the higher management comes to certain conclusions based on informal communications, these findings have to be feed back to the design team.

With respect to the legislation regarding public tender procedures, some caution is recommended towards the communication with the customer. If a public company within the European Union invites companies to tender, they are obligated to write down the official criteria the choice of supplier will be based on and to send the answers on questions, asked by a potential supplier, to all competitor suppliers. Therefor, from the moment the customer releases the call for tender, it could be necessary to arrange, if possible, a mix of official and unofficial meetings (lobby).

Another point of attention is the area of tension between the time that must be invested in the stakeholder and requirement analysis and the time available in the sales phase. The process does not offer guidelines for the percentage of the total sales phase time that should be spend on the analysis and therefor improving the quality of the systems' fit to the environment. This percentage will differ for each project, depending on the complexity of the stakeholders' field, the environment and the offered system.

Engineers do not want to document information if the documentation is the only objective ("document only to document"). Therefor, the reason why the information must be documented must clearly be communicated during team meetings. In the new methodology, the documented information forms the foundation for structured evaluations and supports all team members to be up-to-date the moment a meeting begins. Therefor, there is a responsibility towards the other team members to keep the documentation up with the work.

Sharing and evaluating information in a team means that more people are acquainted with information that could be of value for the competitors of Vanderlande Industries. This understanding of course is the responsibility of each employee of Vanderlande Industries individually, but it can be advisable for the process manager to stress the importance of delicate information usage. Also regarding the documentation of (objective or subjective) information, delicacy can be important.

7.2.4 Evaluation of the way of modelling

The models as introduced in section 5.4 have to represent the real situation in the sales phase on such a level of detail, that on one hand all users of the models can extract the information they need, but on the other hand composing the models will not take too much time. Therefor, the introduced templates for stakeholders and requirements analysis and concept documentation are judged by the involved employees on completeness. During this evaluation several (managers of) Sales and Systems engineers stressed that they were looking for a structured, consistent and uniform way of gathering relevant information based upon which BHS concepts can be designed. The offered templates can replace all kinds of personal checklists and form a good basis that, if necessary, can be tailored to each specific project. The only remark made regarding the completeness was the lack of requirements considering the financing of a BHS (costs are integrated, but not the way these costs are financed).

According to the employees, the cost breakdown structure of figure 5.5 offers enough elements of the life cycle costs of a BHS for this moment. It can be used as a steppingstone on which further details can be applied in the (near) future. The object model of a BHS offers enough detail (right division in object classes and attributes) to quickly represent a BHS concept of Vanderlande Industries. It enables the engineers to build a model by placing and connecting components, based on "thinking in flows" as they are used to do.

7.2.5 Conclusions

Partly due to the participation during the development of the new methodology, lots of aspects of the design methodology are recognised and supported by the employees. The need for more attention for the political aspects of selling a BHS, is confirmed by all involved employees. Combined with a team based design effort and (quantified) justification of design choices, the professional appearance of Vanderlande Industries, the

design process efficiency and the competitiveness of Vanderlande Industries will improve.

The involved employees appreciate the objectives of all documentation activities of the new methodology. It supports the spread of information among team members, it structures evaluation meetings and it guides concerned engineers in founding their design choices on real existing requirements and wishes. The simulation and pricing activities moved to an earlier stage of the design process, got a positive judgement of the employees too. Besides the quantified results, they offer additional insight in the consequences of conceptual changes. The introduced models to be used in the BHS sales phase are judged positively. One remark was made regarding the omission of financing requirements or wishes in the template for the requirements analysis.

Points of interest regarding the controllability of the new methods are the legislation regarding tender procedures, the security of the information that is used during the design effort and the importance of good vertical communication within the Vanderlande Industries organisation.

7.3 Evaluation of design choices justification tool

The evaluation of the design choices justification tool is performed by testing the tool against the requirements as stated in section 6.1 and 6.2. Besides, the tool is judged by several employees of Vanderlande Industries (for a list with names is referred to appendix C). This expert validation is described in sub-section 7.3.2. The final sub-section recapitulates the findings.

7.3.1 Test against the requirements

In the following table the requirements are shown, including the level of compliantness and the characteristics it is based on.

Requirement	Com-pliant	Tool characteristic
Form a guideline in the exploration of the (stakeholders') environment	Yes	The stakeholder worksheet of the tool offers a template for the stakeholder analysis, including hints regarding possible factors of influence.
Applicable for all BHS systems	Yes	It is not required that each field of the templates is filled, so also less complex environments can be documented. The templates can be extended if required.
Stimulate engineers to document their design foundation	Yes	For each part of the designed concept, the relevant requirements must be filled in which offers evaluation and justification possibilities in meetings with colleagues.
Enable efficient and effective knowledge capture	Yes	The gathered information is shared with colleagues and stored in related groups.
Use graphical representations for	Partly	The tool includes edit fields that must be filled with diagrams and layouts. All edit fields in the templates are coloured white,

Requirement	Com-pliant	Tool characteristic
clarification		captured in blue areas containing the hint text. No graphical representation of relations in tool included.
Maintain a common, reusable repository (data / models source)	Yes	The justification tool is used and filled by sales men and engineers. They and also other Vanderlande Industries employees (such as pricing engineers) can reuse each other's work. Besides, the stored information can be used in future projects.
Support team collaboration	Yes	The tool enforces the involved people to discuss the content and to gear the missing information gathering activities. The information recorded in the tool is spread before each meeting, which enlarges the efficiency of the meetings.
Enforce the correct application of methodology and methods	Partly	By combining the requirements including their source and priority with the designed concept characteristics, a well-organised concept evaluation is possible. The tool does not implicit enforce the involvement of colleagues in the evaluation, nor does it enforce a method to gather the required information.
Maintain an "enter once, use often" approach in data collection	Yes	Once the information is documented, all involved employees are able to use it. The different concepts are based on one (and therefor consistent) set of stakeholder and requirements analysis information.
Ensure legitimacy of the tool (the user must understand and appreciate the tool content, application and handling)	Yes	Every involved Vanderlande Industries employee understands the used terminology in the tool. Comments considering content, handling and application are integrated in the development of the tool (participation during development).
Logical and transparent structure	Yes	The general worksheet of the tool explains the relation between the three other worksheet templates. Each template starts with a table of content and the template objective.
Clear user interface (easy to use, also by inexperienced engineers)	Yes	All involved employees often work with MS Excel, so extending/modifying of the templates is easy. All edit fields are recognisable by the colour white, in contrary to the rest in the colour blue.
Extendable (adjustment to dynamic environment must be possible)	Yes	It is easy to add edit fields, hint text or concept templates.
Ensure security of the data that can be of use to the competitor(s)	-	The justification tool is meant to be an internal tool only. Accessibility constraints and portability restrictions must prevent abuse of stored data.
The tool must be kept up to date (consistent and maintained)	Yes	Because the users of the tool have to tailor the tool to each specific project, new relevant aspects are added. The maintenance procedure makes sure these aspects are added to the centrally stored tool templates.
The time necessary for the sales phase should not increase	Yes	The documentation of the results of the stakeholder and requirements analysis takes time. But most of this time can be spend in the period before the call for tender is published. Besides the tool prevents that more than one employee spends time on gathering the same information and meetings are more efficient (everybody is updated and the documentation structure guides the evaluations).

Requirement	Com-pliant	Tool characteristic
Identifying, prioritising and (hierarchically) grouping all the requirements	Yes	The tool offers the edit fields to document the requirements group-wise including priority and ID code.
Keeping up the history of the changes of the requirements	Yes	"Old" requirements remain in the tool. The new requirements are added including an ID code that is derived from the original code.
Seeking certain sets of requirements (bi-directional, from the requirements towards the systems concept and v.v.)	Yes	The standard find-feature of MS Excel can be used to trace ID codes in the concept template (to trace the consequences if a requirement changes). In the concept template the ID's of relevant requirements are mentioned for that particular part of the concept description (to trace the consequences if a concept changes).
Viewing the relations between requirements and system concepts in text/graphical way	Partly	Only in textual way.
Visualising the differences between two versions of requirement sets	No	It is not possible to compare two requirement templates and visualise the differences only. Newer versions of requirements within the same template are recognised by an ID code that is derived from the old requirement.
Generating of reports	No	No definable reports can be printed, the tool layout only.
Performing a validation by checking whether all requirements are consistently related to the concept	No	Besides some defaults, the ID codes of relevant requirements or constraints have to be linked to the concept by the engineer himself. The only way to check the correctness of these links is by colleague validation (during the team evaluations).
Proving the BHS concept is compliant with the gathered requirements from the customer and his environment	Yes	When all requirements and constraints are added in the requirement template and the related ID's appear at least once in the concept template (validated by colleagues), the specific part of the concept can be determined where the requirement is met.

Table 7.1 Evaluation results of test of justification tool against the requirements.

7.3.2 Expert validation

The reactions on the tool were positive. It helps the concerned Vanderlande Industries employees to realise the importance of the process side of the sales phase. Although the methodology is based on predefined steps and templates, it is aimed on dealing with subjectivity and multiple perceptions of reality. The templates integrated in the justification tool form a bridge between the tangible, "content" site and the intangible, "process" site of the BHS sales phase. By guiding the documentation of the stakeholder and requirement analysis, in relation to the concept characteristics, a well-structured evaluation tool comes into being. It offers not only the opportunity to evaluate and justify the concepts themselves, but also the information the concepts are based on. The requirements as stated in a call for tender for instance, can be approached in different ways. In Eastern Europe the supplier of the BHS determines the way the requirements

have to be interpreted. The customer only tests the concept against international standards (e.g. the noise level standards). In Western Europe the customer determines the way the requirements are interpreted. The standards are only guidelines and (in most cases) expensive, so interpretation of the requirements in a "creative" way can save money. If all involved Vanderlande Industries employees are aware if these interpretation differences, achieved by completing and sharing the tool content in a team-based effort, the chance of offering the right system to the right customer gets bigger.

The only wish regarding the current content of the tool was to integrate financing aspects of the BHS too. For now, the tool includes life cycle cost, but not the way these cost are financed. According to some experts the financing agreements (such as involving a bank in order to buy the BHS and to sell it to the airport after a couple of operational years in order to earn money first) get more relevant each day. A requirement or constraint table should be added to the justification tool to include this aspect in the requirement analysis.

It is hard to perform a cost/benefits analysis, because the benefits of the tool can not be expressed quantitatively. The tool improves the quality of the designed concepts, realised by structured and agreed upon foundation of conceptual choices based on both content and process aspects, which must lead to a better fit of the offered concept to the requirements of the customer's decision makers. To implement the tool in the organisation, resources such as people, PC's and MS Office software are available. But in addition to that, cost regarding the security, accessibility and maintenance of the tool have to be made.

7.3.3 Conclusions

The justification tool is well received by the employees. They are convinced that the correct use of the tool will improve the quality of the designed concepts, realised by structured and agreed upon foundation of design choices. This foundation contains both technical and social aspects. Using the tool means dealing with subjectivity and multiple perceptions of what is "good" by filling predefined templates and evaluating the information.

Direct benefits of using the justification tool:

- Guidance of the analysis and documentation of the stakeholders network and requirements
- Guidance of the documentation of the BHS concept design choices
- Guidance of the foundation of the design decisions
- Preparation tool for the team kickoff meeting (everybody well informed)
- Guidance of the structured team evaluation of design choices and the information they are based on

Indirect benefits of using the justification tool:

- Possibility for inexperienced engineers to learn from earlier projects
- Possibility to reuse work in other projects (because all conditions are known)

7.4 Evaluation of the simulation tool

In sub-section 7.4.1 the simulation software evaluation framework of Nikoukaran is used to determine the suitability of the chosen simulation package for the support of the BHS concept design. In sub-section 7.4.2 the test against the requirements on the simulation tool is described, which includes the making of three simulation models. In the final sub-section, 7.4.3, the evaluation results are summarised.

7.4.1 Test against evaluation criteria

The criteria of the framework of Nikoukaran based on which the evaluation of the ED simulation package is executed, are described in table 7.2 [Nikoukaran, et al, 1999]. Below the table the summary of this evaluation is given. For the complete overview of the evaluation is referred to appendix I. This appendix also includes the description of the BHS objects that exist in the BAXSIM library (section I.10 of appendix I).

Criteria	Explanation
Vendor	Criteria related to the credibility of the vendor and to some extend his/her software
Model and input	Issues related to a model, its developments and data input
Execution	Issues related to experimentation
Animation	Issues related to creation, running and quality of animation
Testing and efficiency	Issues for evaluation of testability, debugging power and efficiency of a package
Output	Kinds of output and included analysis instruments
User	Needs and circumstances to be able to use the simulation language

Table 7.2 The criteria for the simulation tool evaluation.

Vendor
The vendor of ED, Incontrol Simulation Software B.V., gained experience in modelling BHS in projects for Amsterdam Schiphol Airport. They give training courses in how to use ED on several levels of experience. Besides their helpdesk, the thorough user manuals help the (in-)experienced simulator in getting started easy.

Model and input
Building a model in ED is a combination of configuration (dragging objects in the model and connect them) and parameter setting via menus. This offers a quick way of building high-level BHS models by inexperienced engineers, suitable for the conceptualisation steps in the sales phase (see below the description of three models that were built). The flow aspect makes it easier to understand what happens in the model because the bags can actually be traced through the model. The object aspect makes it possible to easily exchange, extend and reuse (parts of) models. The objects offer enough openness for further (programming) detail (e.g. acceleration of conveyors). However, this requires more knowledge of the package and 4Dscript, the ED programming language.

Execution
Regarding the execution of simulation runs, ED offers the possibility to run the model at different speeds and to predefine multiple runs including run length and initial start-up period.

Animation
The 2D animation of ED is very simplistic, but offers enough detail to get a good insight in the behaviour of the system and the baggage flows. The status of an object can be represented by colours. Tables and graphs can be shown during a run. The 3D animation is generated automatically and offers more presentation and validation power than the 2D layout. The AutoCad drawing of the terminal building can be used as background of the animation. Missing are standard drawing features like lines and coloured shapes which could support the engineer in arranging the models in a convenient way.

Testing and efficiency
Although not very precise, the error messages that pop up when bugs are found in the entered logic support debugging. Further validation and verification support is offered by the animation and the possibility to monitor the basic utilisation characteristics of all objects such as throughput, average content, maximum content and status percentages.

Output
Concerning the content, the standard output delivered by ED covers the data needs of the engineers, except for one issue. The travel times of bags in the model are represented as histogram data only (number of bags per interval of time) while in some cases the average and maximum travel time is required too. Regarding the presentation of the output it is too much spread through the model. For now the easiest way of grouping the results is by copy and paste the data from the ED tables into MS Excel.

User
To work with ED only a couple of days are necessary to learn the basic features. So the package is ideal for engineers with no or little simulation experience.

7.4.2 Test against the requirements

As described in section 6.3.1, the Sales and Systems engineers require insights in the performance of BHS concepts regarding maximum throughput, utilisation measure of resources and travel times of bags. To evaluate the simulation tool from this user point of view, three simulation models were built of BHS in different levels of detail. The objective was to answer questions the engineers often have and which play an important role in the design phase of a BHS. By joining a meeting of several sales engineers in the German Customer Centre, several questions came up such as:

- Is it possible to rearrange the input configuration around the tilt-tray sorter in order to lower the utilisation (or to sort even more bags)?
- If case of TUBTRAX®, how many tubs are necessary in the system? And where should tub buffers be placed? And how many tubs must they be able to buffer?

- Regarding redundancy, what are my system performances (throughput, travel times) when a part of the system fails?

Figures 7.1, 7.2 and 7.3 show the three simulation model layouts. The first one, the model of figure 7.1, was quite detailed and answered questions regarding the travel times of the bags and the utilisation of the HELIXORTER® in a satisfying way. The travel times were copied in MS Excel to make graphs. The results considering the utilisation of the sorter are integrated in the simulation tool itself. Building this model required one day for the modelling and another two days for the verification, validation and output analysis. The Sales and Systems engineers involved in the evaluation were unanimously positive about this building time.

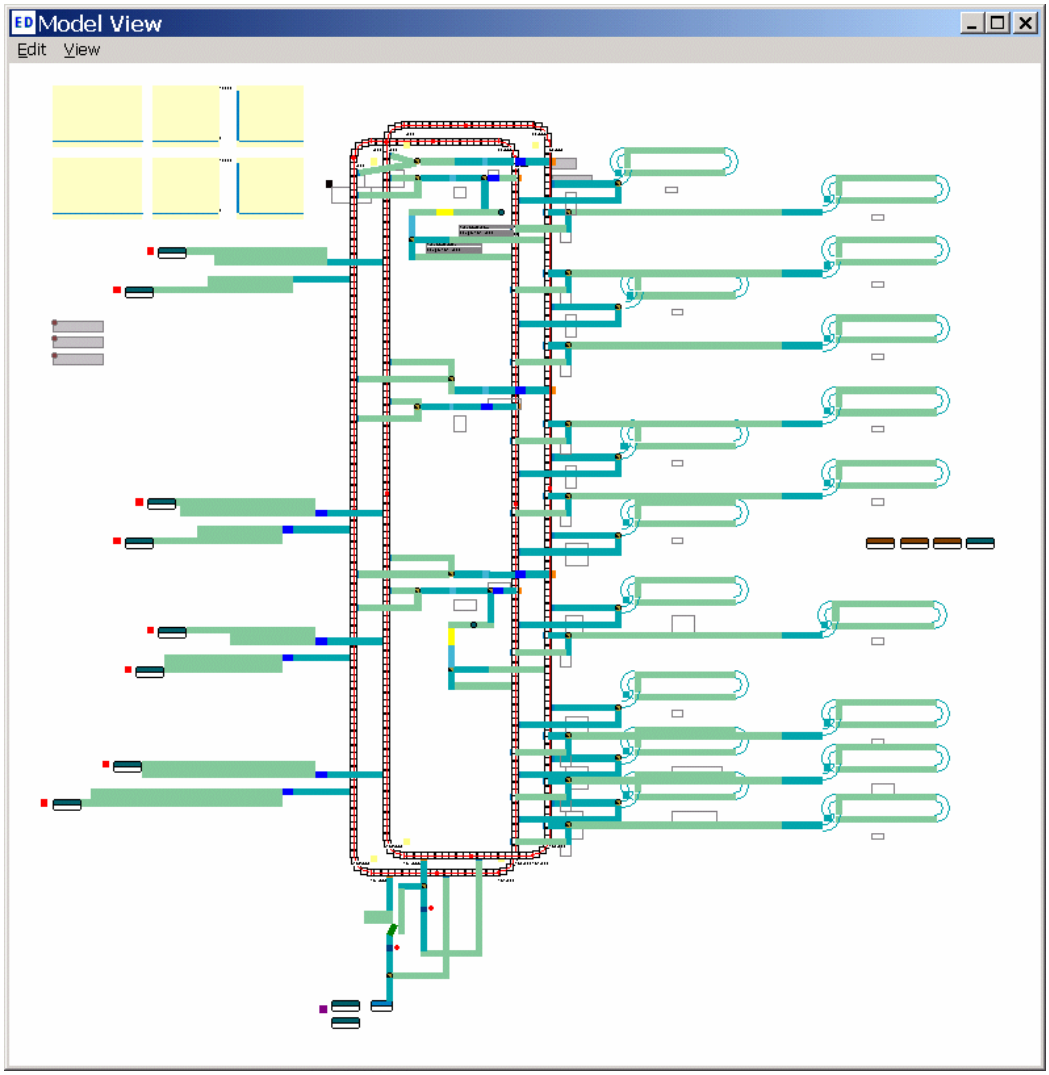


Figure 7.1 2D model layout of the first BHS simulation model.

The second model was built on a high level of abstraction and provided the answers about the empty tub management. As can be seen, the connections between the different areas are represented by a simple network of conveyors. There are local areas distinguished with lower conveyor speeds and scaled transit lines (between terminal buildings) with

higher speed. These speeds can be changed for all conveyors centrally, just like the initial number of tubs in the central and three local buffers. There are monitors connected to the local buffers that display how many times and for how long a bag had to wait for an empty tub. Building this model took about two days including optimising the controls. So the simulation tool enables the Sales or Systems engineer to answer questions about buffer locations, dimensions and numbers of tubs (or carts) within two days, including insights in the results of different control algorithms.

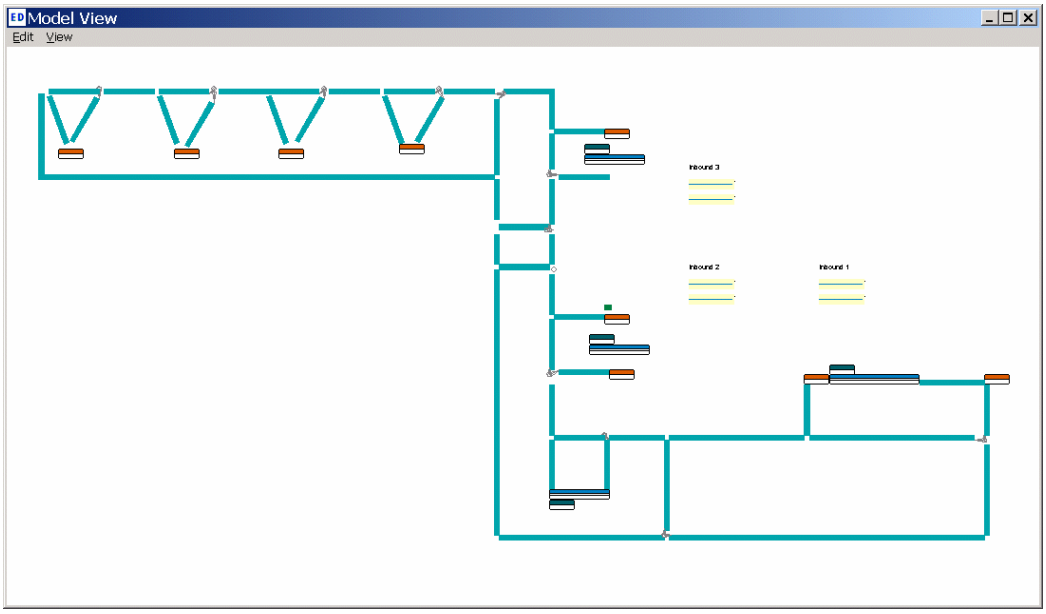


Figure 7.2 2D model layout of the second BHS simulation model.

The third model made of a BHS was able of predicting the maximum possible throughput for two check-in islands and a transfer line. The distribution over the sorter was changed by different controls and layouts alternatives (scenarios). This offered very much insight in the system's behaviour. Building the model took about one day. Changing the controls was easy, but changing the configuration of the sorter takes more time because adding inducts and/or chutes is complicated. If the configuration alternatives are known at the moment the sorter is modelled, the extra needed inducts and chutes can already be included in the model which reduces the required modelling time.

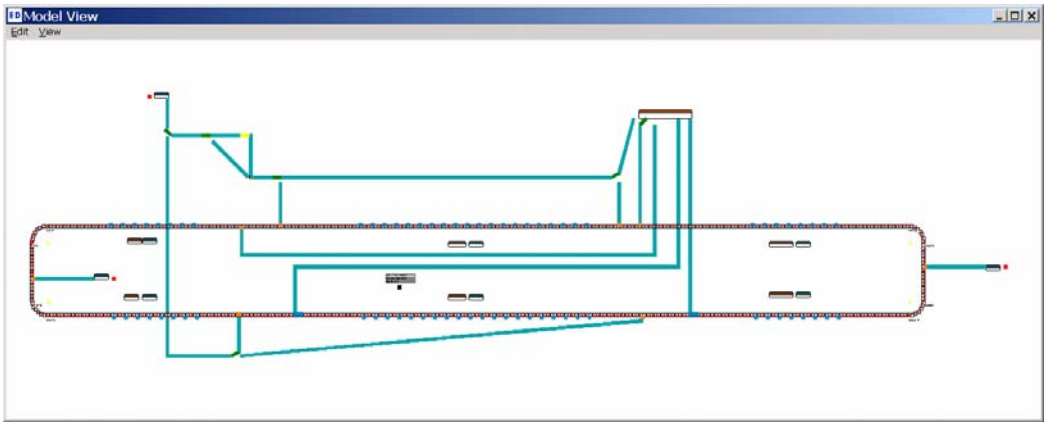


Figure 7.3 2D model layout of the third BHS simulation model.

In order to represent the BHS in a right way, the completeness of the simulation tool regarding the components which are applied by Vanderlande Industries in BHS solutions is evaluated (table 7.3).

Object class	Completeness BAXSIM library (version 1b) in ED
Input	Nothing missing.
Transport	The instance BAGTRAX® is not included (according to the supplier available in the latest version of the library). Instead of the attribute "maximum peak capacity" the objects have the "gap length" attribute (in combination with speed the same functionality).
Process	The instance EBS can be represented, but without the distinction between lanes, racks or dynamic EBS. The instance Screen can be represented, but without the distinction between levels 1&2 or 3. Reconciliation can not be represented.
Output	Nothing is missing.
Sort	The instance tilt-tray sorter can be represented, but without the distinction between the normal sorter and the HELIXORTER®. The instances pusher, vertibelt and cross belt can not be represented. Their functionality can be simulated with the object lateral.
Merge	The instances vertimerge and end merge can not be distinguished. The functionality of the instance side merge is missing in the library (can be represented by splitting the conveyor to which is merged in two conveyors).
Bag	Nothing missing.
Controls	High level controls object is missing.
Employee	Available in the standard ED logistic library.

Table 7.3 Completeness evaluation of the BAXSIM library.

The objects included in the ED simulation package and the BAXSIM library are compared with the object classes and their instances of a BHS as defined in appendix H. The level of detail of these objects is tuned to the minimum required insights and simulation results in the design phase of a BHS concept. The distinguished object classes are represented in the left column of table 7.3. The right column contains the comments regarding the completeness of the BAXSIM library.

Most of the BAXSIM library objects are more detailed than the required level of detail in the design phase. Although not necessary for the behaviour study of a concept, it does provide more detailed layouts and animation that can enlarge the trust in simulation models. To get the whole library on this level of detail, the vertimerge, pusher and vertibelt should be added to the library.

7.4.3 Conclusions

Summarising, the ED simulation package in combination with the BAXSIM library offers the Sales and Systems engineer a useful tool to justify conceptual choices regarding configuration and technology. It is detailed enough to give insight in system behaviours and answers questions concerning the system performances. If very detailed models are required (e.g. including acceleration and decelleration of the conveyors, photocells to determine whether a bag is sorted out or not, etc.) it is possible to program it in ED by experienced users, but it might be wiser to build the model in AutoMod. AutoMod is used by the simulation department of Vanderlande Industries and offers more detail through programming code.

The cost of the introduction of ED at the engineers' workplaces will exist of software licenses, possible hardware upgrades and training time. Building simulation models requires time of the engineer. The benefits of using ED by the Sales and System engineers can be diverted in:
Direct benefits of using the simulation tool:

- Optimisation of the BHS design improves the purchase price/performance ratio and therefor the level of competence with competitors' designs
- Accurate and insightful system design eliminates unnecessary rework costs

Indirect benefits of using the simulation tool:

- Accurate system depiction ensures valid decision-making information
- Improved system performance improves customer satisfaction
- Increased understanding of the system behaviour
- Integrated simulation projects improve team communication

7.5 Evaluation of the cost calculator

The evaluation of the cost calculator is based on a test against the requirements as stated in section 6.4 (described in sub-section 7.5.1), verification of the calculator (7.5.2), a replicative validation (7.5.3) and an expert validation (7.5.4). Finally, the results are recapitulated in sub-section 7.5.5.

7.5.1 Test against the requirements

In table 7.4 the requirements for the cost calculator as stated in section 6.4 are shown in the left column. The level of compliance to these requirements including explanation is given in the other two columns.

Requirement	Com-pliant	Tool characteristic
Easy to use, also by inexperienced engineers	Yes	Once the engineer is familiar with the ED simulation package in order to determine the dynamic behaviour of a concept, performing a calculation is very simple (by dragging the LCC calculator into the simulation model). The input data is entered via menu steps. In order to get the required input data colleagues have to be consulted (or at least the input data has to be verified). Maintaining the calculator requires more knowledge of ED and the 4Dscript (ED programming language).
Performing a calculation should not take too much time	Yes	If there has already been built a simulation model of the concept, the only time spend on the calculation is verification time for the input data. If no simulation model is required, a calculation also implies dragging all concept objects into the model with the right physical dimensions (no connections or logic needs to be entered!). For a mid-range airport system this will take approximately 1.5 hour which is satisfying.
Logical, transparant structure	Partly	By menu options the structure of the LCC elements that are taken into considerations is clarified. To find out how the calculation of the Capital Expenditures is performed, it is necessary to read the 4Dscript of the calculator (including the hint text) or to read the explaining appendices K and L of this report.
Extendable	Yes	By adding 4Dscript the menus and calculations can be extended.
Security of confidential information	Yes	The way the calculations (object prices, calculation steps) are made are not shown in the results (no content of the tool is shown).
Information must be kept up-to-date	Yes	The results must support team-based evaluation of concepts and the information they are based on. This also implies an evaluation of the tool itself. A documented maintenance procedure must secure that extensions/changes are integrated in the tool.
Documenting the results must be easy	Yes	It is possible to copy and paste the model layout of the calculator in the justification tool (including input data). Besides it is possible to copy and paste the “total cost graph” or the data the graph is based on.
Rough LCC amounts in order to compare BHS concepts	Partly	The Capital Expenditures are calculated quite accurate (see below) and are therefor suitable for comparing concepts. The input data necessary for the other elements has to be verified with colleagues in order to found conceptual choices on the results.
A graph that represents the total cost per year of the life cycle	Yes	Besides the total cost per year (bar graph or cumulative graph), it is also possible to display the cost per year for one or a combination of cost elements in the graph.

Table 7.4 Evaluation results of the calculator tested against the requirements.

7.5.2 Verification

The verification of the cost calculator is performed in iteration with the making of the calculator. The input variables are checked on correctness and typing errors. By performing several calculations during the making of the calculator and comparing the results with expected values, the calculation logic was checked.

7.5.3 Replicative validation

Because of the relevance of the capex (Capital Expenditures, purchase price of complete installed BHS, including high level controls) calculation, an airport test case is used to validate the calculation performed by the calculator. The BHS of airport Köln-Bonn in Germany is used because of the availability of both the Capital Expenditures calculation used for the quotation (including the high-level controls price) and a AutoCad-drawing of the layout. In figure 7.4 the model layout is shown upon which the cost calculation was made. Note that it is necessary to drag the right objects with the right dimensions into the model, but that no connections or exact locations are required. E.g. the chutes (points where the bags leave the tilt-tray-sorter, in figure represented by blue squares) are al grouped at one place in the sorter, while in reality they are distributed along the sorter's side.

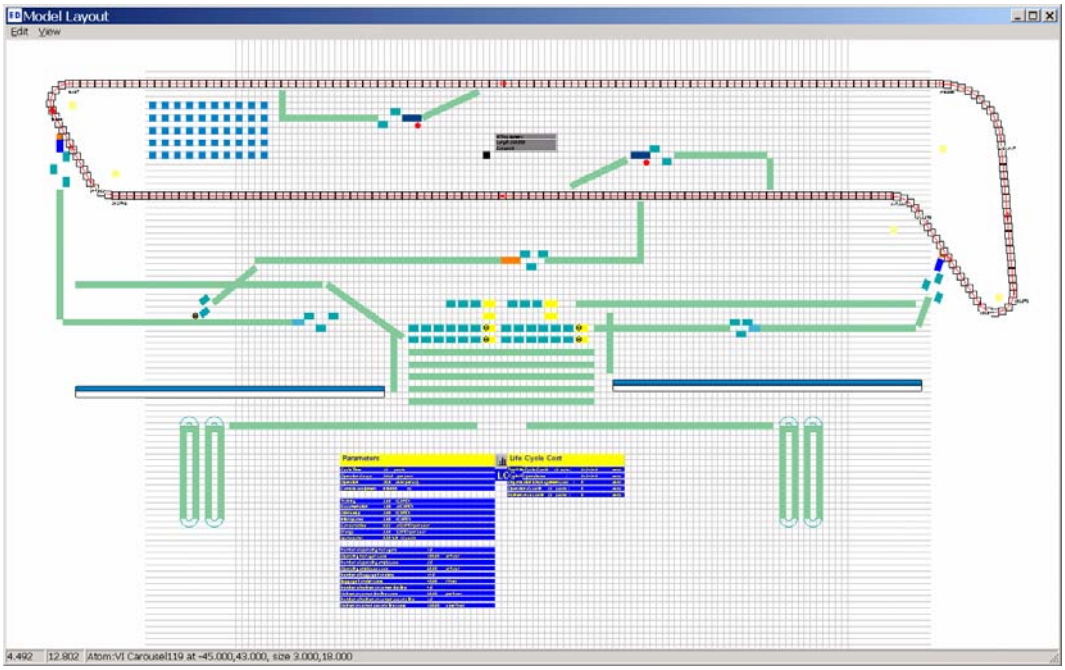


Figure 7.4 Cost calculations layout model of the Köln-Bonn BHS.

After entering the price of the high-level controls system (detailed price was available) via the input menu of the calculator, the capex were given. The capex amount calculated by the tool was 5.0% too high[2]. The prices of BHS components did not increase for the last five years (source: Vanderlande Industries, JG) so inflation can not account for the difference. Therefor the capex calculations can be said to be accurate enough to indicate the system price, but not detailed enough to use calculation results in (detailed) external communications.

However, each user of the cost calculator must be aware of the way the calculation is made before using the results (calculation rules are included in appendix L) in order to recognise and integrate deviating situations in the calculation.

7.5.4 Expert validation

While evaluating the cost calculator with Vanderlande Industries employees it became clear that in this stage the calculator is a powerful tool regarding capex calculations. In contrary to a calculation in a spreadsheet, the calculation is based on a layout including physical dimensions. This is much more convenient and, especially when the simulation model is already built, faster. For now the calculations of the other life cycle cost (LCC) elements can only be used in a guiding way to make the engineers familiar with different LCC and to elicit and encourage discussions with colleagues about, in order to elaborate the LCC knowledge. All employees find the chosen diversion of the costs in the elements as shown in the cost breakdown structure in figure 5.5 offers enough detail to distinguish different concepts for now and the near future. It offers a framework in which new knowledge can be stored.

7.5.5 Conclusions

The cost calculator enables the Sales and Systems engineers to easily (via menus) calculate a reliable estimation of the investment costs of a BHS. The calculation can be performed very quickly and is based on a schematic layout of the BHS including physical dimensions, which is more convenient than a (textual) spreadsheet. The results are presented as numbers and in two different graphs and can be exported to e.g. the justification tool. Besides the investment costs there are other life cycle cost elements included, which in the current stage mainly can be used to elicit attention and discussion. These elements are not calculated with enough detail to directly use the absolute results.

Direct benefits of using the cost calculator:

- Offers (quantified) insight in the consequences of changes in BHS concepts for the life cycle costs integrated in the concept design process
- Calculations are based on schematic layouts which eliminates the chance of forgetting parts of the system

Indirect benefits of using the cost calculator:

- Offers the engineers who are unacquainted with LCC something to hold on to
- Structures (team) discussions regarding LCC

7.6 Summary

In this section the evaluation findings as presented in this chapter are summarised.

[2] The amounts are confidential. The calculation was performed without taking the deviating lifts at the check-ins into considerations. The price of these lifts, subtracted from the detailed calculation performed in 1997, was estimated by JG.

The methodology and tools are not evaluated by using them in a real sales phase, because of the limited time available for this master project. The methodology is evaluated by confronting employees of Vanderlande Industries with the different aspects of the methodology and the supporting tools. Besides, the tools are tested against requirements as stated beforehand and are applied in test cases.

The participation during the development of the methodology resulted in recognition and support of the employees. All of them (see list of names in appendix C) think that the proposed attention for the decision process of the customer, the more team based design effort and the (quantified) justification of the design choices can improve the professional appearance, the BHS design process efficiency and the competitiveness of Vanderlande Industries. The suggested activities are judged positively. Regarding the controlling of these activities, some points of attention are mentioned, such as the legislation regarding tender procedures, the security of information and the importance of not only the horizontal communication within Vanderlande Industries, but also the vertical communication.

The conclusions considering the justification tool are that correct use will improve the quality of designed BHS concepts by structured and agreed upon foundation of design choices (both technical and social). It guides the user in the analysis, documentation and evaluation of the stakeholders network, the total set of requirements and the designed concepts. The tool content forms preparation material for meetings and enables engineers to reuse or learn from earlier work.

The simulation tool is useful to support the justification of conceptual choices regarding configuration and technology. It offers enough detail to get a better insight in the BHS behaviour and (related) performance. Therefor it enables the engineers to optimise designed concepts which improves the competitiveness of the Vanderlande Industries solution. By offering insight in an early stage of the design process, rework in latter stages can be prevented. Next to better founded decision making, the (dynamic) depiction of the system offers a good communication tool to discuss BHS concepts.

To conclude, the cost calculator enables the Sales and Systems engineers in easily and quickly calculate a reliable estimation of the investment costs, based on a schematic layout. The results are presented in numbers and graphs and can easily be exported and communicated. The calculation tool supports the engineer in comparing different concept alternatives regarding the defined life cycle cost elements. The elements other than the investment costs are mainly applied to elicit attention for and discussion about these aspects of costs. The calculations are not detailed enough to use the absolute numbers.

8 Suggested implementation plan

How to implement the new methodology and tools as introduced in the previous chapters in the current organisation of Vanderlande Industries? This question is briefly answered in this chapter. It is not meant to be an exhaustive plan, but offers guidelines for the main aspects of the suggested implementation.

The first section deals with the nature of the change implementation at Vanderlande Industries' organisation. Section 8.2 describes how to start the change by testing tools and methodology in a pilot project. The final section, 8.3, describes the actual implementation and related activities in case the results of the pilot project are satisfying.

8.1 Designing versus developing the organisation

In the literature a distinction is made between designing an organisation and developing an organisation [Twist, van, Edelenbos, 1999]. Design implies a radical change of the formal organisational structure by starting from scratch and ignoring the existing structure. Development implies a learning aspect, meaning an incremental change of the (informal) organisational structure. The approach of the change depends on the characteristics of the situation [Twist, van, Edelenbos, 1999]. In case of a threatened continuity of the organisation (crisis situation) and the existence of big conflicts among the employees, the design approach is preferred. In case the organisation functions quite well, but improvements are desired, based on a considerable level of agreement, the development approach is recommended. The characteristics of the situation at Vanderlande Industries fit the characteristics related to the development approach. But to get the development started, a combination of both approaches is suggested. The developed design methodology, including supporting tools, forms the starting point from which the organisation can develop into the desired direction. The one-time change in process activities must lead to continuous improvement. The new process plays a directive role in further development.

8.2 Pilot project

Because (most of) the process activities and the tools are not applied in a real sales phase situation yet, the benefits as stated in this thesis are not ensured in practise. Therefor, before implementing the new process and tools, they should be applied and evaluated in a pilot project. Measurement of the actual results regarding the number of sold BHS projects is hard to perform because most improvements are qualitative and their impact is, even in the future, hard to measure due to complex influences of all kind of unpredictable factors. Therefor, feedback on the proposed changes of the employees is very important in order to judge whether the process of change is on the right course. It is hard to

quantify this judgement but the answers to the following questions can lead in qualitative judgement:

- Did the involved employees work in conformity with the way of working as introduced in this report?

  By interviewing the involved employees and going through the minutes of meetings and (intermediary) products, the performed activities can be compared with the activities as described in the process models. If the real activities differ from the suggested activities, the reason(s) for this deviation must be found. Were process descriptions clear? Were all elements of the way of controlling effective? Do all employees recognise the benefits of the new approach? Was the time available in the pilot project sufficient for all activities? Etc.

- Did the involved employees use the introduced tools in the correct manner?

  By interviewing the involved employees and taking a closer look at the products/results of the usage of the tools, correct use can be assessed. If the tools were not used in the way as described in this report, the reasons for this deviation must be found. Was the training sufficient? Did the tool enforce a correct use? Did the time necessary to use the tool exceed the available time? Was the user-interface adequately? Etc.

- Did the new methodology result in clear justified BHS concept choices?

  A possibility to find the answer to this question, is to compare a BHS concept including accompanying documentation as designed in the current situation with the designed concept of the pilot project. An employee, who was not involved in the design of one of the two concepts, should judge the clearness and completeness of the justification of the design choices that were made. Does the concept documentation of the pilot project offer a better insight in the foundation of the concept? With other words, does the documentation answer in a structured way the questions why certain choices are made? Does the concept documentation offer the possibility to trace all assumptions in order to reuse (parts of) the work done in the pilot project for other BHS projects? Etc.

- Is the designed concept in the pilot project well tuned to the total set of requirements and wishes?

  Although it is not possible to examine the correctness and completeness of the set of requirements afterwards (a lot of stakeholders are not to be contacted anymore), it can be compared with the official reasons why a customer did or did not choose Vanderlande Industries to be the supplier at the end of the sales phase. In some situations lobby activities after this decision of the customer could possibly reveal other, non-official reasons and requirements.

An evaluation team must be formed to determine whether the expected changes did occur. Advised members of such a team are employees related to Knowledge Management, with contacts at all different departments related to the BHS sales phase. This evaluation team should eliminate the current uncertainties and communicate the (intermediary) evaluation results towards the potential users, in order to create support for

and understanding of the new methods and tools. In case the course of a pilot project showed extreme abnormality, it could be wise to consider the start up of another pilot project.

Note that it is possible, and even advisable, to split the presented solutions of this master research when starting pilot projects. The simulation tool, and therefor also the cost calculation tool, should be used in a pilot project at a Customer Centre situated in the Veghel office, because of the presence of simulation engineers. These engineers can, if necessary, support the user (a Sales engineer of Benelux or International or a Systems engineer of the Systems Group) and answer questions related to the software package. Besides, the Pricing engineers are situated at Veghel what makes communication about the calculator contents easier. Training of the concerned Sales or Systems engineer can be done by reading the Enterprise Dynamics Users Manual and making example models, if necessary supported by a simulation engineer. To understand and correctly use the calculation tool, sections 5.4, 6.4, 7.5 and appendices J, K and N of this report should be read. The BHS that must be designed in this pilot project should reach a certain level of complexity (the number of passengers per year should exceed a million) to point out the benefits of the tools and related activities.

The other parts of the new methodology, including the design choices justification tool, should be tested in a pilot project in a Customer Centre outside the Veghel office. This part of the solution, considering the activities related to attention for the decision process of the customer, the teamwork regarding information elicitation and evaluation and documented justification of the design choices, is mainly “formed” in Veghel. Parts are results of interviews with employees of the Veghel office, and therefor it should prove its benefits in a “world outside Veghel”. The Customer Centre in Germany or Spain is recommended to start the pilot project, because according to the Management of the Systems Group, these Customer Centres have a relatively open mind towards new, more customer-focused activities. The employee who will play the role of process manager can introduce the new methodology at the CC and start up the pilot. Again, the BHS to be developed should imply a certain level of complexity towards the stakeholders network in order to reveal the benefits of the methodology and tool.

8.3 Actual implementation

If the results of the pilot projects are satisfying, the new methodology can be introduced in the whole Vanderlande Industries organisation. Because of the learning aspects of the process, it is very important that the participants have an understanding of and appreciation for the methods and tools that are used during a project and afterwards to institute continuous process improvement (CPI) [Mayer, 2001]. So, the new methodology and tools should be explained to all involved Vanderlande Industries employees to gain support, commitment and a social basis for the new situation. It offers the breeding ground for continuous learning and implementation of improved process aspects.

The following implementation activities have to be controlled by employees responsible for the implementation (members of the Knowledge Management team):

- Introduce the “way of thinking” of the methodology in the organisation
- Write procedures for the forming of design teams
- Write procedures for the division of responsibilities, tasks and authorities of the members of a design team (minding the management of the balance between process and content)
- Create and maintain formal communication channels
- Write procedures for decision-making activities (minding the evaluation moments)
- Register the new tools
- Write procedures concerning the accessibility of the tools
- Write procedures concerning the maintenance, extension and security of the tools
- Arrange the proper training for the involved employees (regarding new activities and tools)
- Arrange frequent evaluation and feedback moments for the new process and tools

9 Conclusions and recommendations

This chapter summarises the findings of this master thesis and includes some recommendations for further research, resulting from this thesis. The first section (9.1) starts with the conclusions. Section 9.2 contains the recommendations.

9.1 Conclusions

The conclusions of this master thesis comprehend the following.

Initial problem verification

The existence of the initial problems as stated by the involved employees of the Systems Group, could not be confirmed by a quantitative analysis because of the lack of relevant data. Therefor, the initial problems were verified by interviewing employees of different departments of Vanderlande Industries. All interviewees recognised the initial problems.

Underlying problems

Analysis of the current situation in the BHS sales phase, based on implications of the stated objective, revealed the following underlying problems:

1) The employees of Vanderlande Industries who are involved in the sales phase of a BHS pay too little attention to the complex context of the decision process of the customer and therefor possibly not make the best of their chances to influence that decision.
2) The employees of different departments and Customer Centres of Vanderlande Industries who are involved in the sales phase of a BHS do not work as a team regarding:
    - The elicitation, interpretation and documentation of information regarding the total set of requirements on a BHS
    - Structured evaluation of design choices made in the BHS design process
3) The Sales and Systems engineers of Vanderlande Industries do not adequately document their quantitative or qualitative foundation of the design choices that are made in the design process of a BHS.
4) The Sales and Systems engineers of Vanderlande Industries seldom integrate quantitative results of dynamic behaviour and cost analysis in the BHS design process.

General solution directions

Based on common sense and a literature study, solution directions are distinguished to solve these problems. An analysis of the involved stakeholders, including their interests and perceptions, offers the opportunity to handle the aspects of a complex stakeholders network and to predict or even influence the (strategic) behaviour of stakeholders [Enserink, e.a., 1999]. The (dynamic) requirements of these stakeholders on a system

should be identified in an early stage and have to be tracked and traced through the design effort in order to ensure a good fit between system and requirements [Hooks, Farry, 2001].

Attention for the strategic behaviour of stakeholders should not go without justification with regard to the content [Bruijn, de, Heuvelhof, ten, 1999]. Documentation of the reasons why certain technical choices were made offers efficiency benefits in the design effort and allows structured and unambiguous usage of this knowledge by other colleagues when operating in the social network. To quantify and enlarge the insights on which the justification of design choices is based, automated tools can be used. Simulation studies on a computer can offer insight in the dynamic behaviour of complex systems [Arsham, 2001]. Regarding the costs of a system, analysis of not only the purchase costs, but also other system related cost aspects such as costs for required operations and maintenance resources, offers information based on which design decisions can be made [Ludema, Roos, 1998].

Regarding the organisational aspects of a design effort, involvement of all disciplines in an early stage can create commitment and a "team-feeling" [Bruijn, de, Heuvelhof, ten, 1999] which can offer efficiency and quality improvements. To support and guide the team communication in a creative design process, information and communication technology can be useful.

To make the different levels and dimensions of a various improvement effort with attention for the organisation, processes and supporting technology explicit, a design framework can be used [Sol, 2000a]. Part of this structure can be a design methodology, defined as a coherent set of activities, guidelines and techniques that can structure, guide and improve a complex design process [Meel, van, 1993].

Suggested solution: a new methodology and supporting tools

In combination with suggestions of employees, application of these notions to the situation at Vanderlande Industries, resulted in the development of a new design methodology. Based on evaluation results, the expectation is that adaptation of this methodology in combination with the three supporting tools as introduced in this thesis will solve the defined problems.

The methodology is based on the thought of a better mix between technical/content aspects and social/process aspects in the BHS sales phase at Vanderlande Industries. Table 9.1 shows the main elements of the new methodology, in relation to each other and the developed and/or evaluated supporting tools.

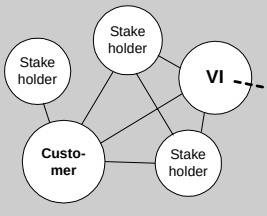
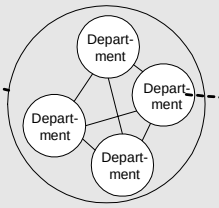
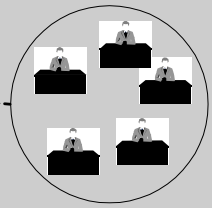
	Macro	Meso	Micro
	 Cooperation of organisations	 Coordination of processes between VI departments	 Primary tasks at workplace level
Way of thinking	"Getting grip on the decision process of the customer"	"Teamwork regarding evaluation and information processing"	"Integral justification including documentation of design choices"
Way of working	- Lobby - Stakeholders analysis - Requirements analysis - Feedback elicitation	- Team formation - Team based evaluation	- BHS design choices justification & documentation - BHS dynamic behaviour analysis - BHS cost analysis
Way of controlling	Process manager Commitment Drop out prevention Support Responsibilities division & documentation		
Way of modelling	Stakeholders analysis template Requirements analysis template	BHS concept design choices justification	BHS concept description template Simulation model Cost breakdown structure
Supporting tools	Design choices justification tool		Simulation tool Cost calculator

Table 9.1 The new design methodology including the supporting tools.

The developed design choices justification tool is a MS-Excel document containing templates for the stakeholders network analysis, the requirements analysis and the documentation of a BHS concept including justification of the design choices. The existing simulation tool (software of Enterprise Dynamics including the BAXSIM library) is a graphical oriented simulation package including BHS objects. The third tool, the developed cost calculator, is based on the simulation tool and contains different elements of life cycle costs with the emphasis on the investment costs.

Benefits new methodology

Evaluation sessions with employees of different departments and Customer Centres showed appreciation and support for the suggested methodology and tools. It is broadly recognised that introduction will help reaching the stated objective, which implies improvement of the professional appearance, the design process efficiency and the competitiveness of Vanderlande Industries. Therefor, Vanderlande Industries is advised to implement the design methodology and supporting tools as introduced in this report.

Pilot projects

The methodology and tools are not evaluated in reality yet. Therefor, before implementing the methodology and tools in the entire organisation, Vanderlande Industries is advised to evaluate them in real situations in pilot projects.

9.2 Recommendations

As concluded above, Vanderlande Industries is advised to implement the introduced methodology and supporting tools in pilot projects. In this report different aspects of improvement of the BHS sales phase are explored. Based on these findings, several recommendations are made for further improvements concerning the future processes at Vanderlande Industries. Recommendations regarding efficiency improvements are included in sub-section 9.2.1. In sub-section 9.2.2 two recommendations are discussed concerning further research on the cost aspects of a BHS.

9.2.1 Efficiency improvements

To start with, in general standardisation of procedures, methods and tools and the reuse of work improve the efficiency of processes in organisations. Introducing standardisation in procedures and methods at different departments improves the manageability of the organisation. Standardisation in the supporting tools improves the return on investment (training and purchases) and the adjustment of (intermediary) products. Applying this to the situation at Vanderlande Industries results in the following recommendations.

Tailoring methodology and tools to usage by other disciplines

Many aspects of the methodology and the tools apply to the sales phase in general, not only for the baggage handling systems. Therefor it should be wise to research the possibilities for tailored versions of the process and tools in the sales phase of the other disciplines (Warehousing and Distribution, Express Services Industry and Manufacturing Industry).

Research on reusing work in phases after the sales phase

Vanderlande Industries is advised to start research on the reuse possibilities of the products of the sales phase in following phases. E.g. the reuse of the “model object tree” of the simulation tool, which contains all objects (read: components) applied in a BHS concept, to create a bill of material for the purchase department or to support the planning of the manufacture department. Another example is the use of the information in the design choices justification tool in the engineering phase in order to clarify why certain design choices are made and therefor prevent misjudgements.

Tracking AutoCad / Enterprise Dynamics linking

The supplier of the ED software mentioned developments regarding the linking of objects in ED with components in AutoCad. Vanderlande Industries is advised to keep up to date considering these developments to exploit possible efficiency improvements if CAD

engineers and Sales, Systems or Simulation engineers could exchange intermediary products. This could imply reuse of work and fewer mistakes when converting the different products between AutoCad and ED.

Involvement in BAXSIM library development

Vanderlande Industries, in the role of potential customer of Enterprise Dynamics, is recommended to keep involved in the development of new releases of the BAXSIM library. Involvement offers a voice in the matter of which features and functionalities will be added in the near future to the library. Besides it offers influence in the terminology used in the library. That way the BAXSIM library will keep up-to-date to the product range of Vanderlande Industries which enlarges it usefulness.

9.2.2 Cost aspects of a BHS

The purchase price of a complex system can be just a fraction of the total related costs that have to be made during a life cycle of such a system. Insights in these total costs can be powerful tools for the customer when evaluating different systems on the criteria of return on investment. Vanderlande Industries can exploit the results of the life cycle cost calculations by using them in those situations it positively influences the decision process of the customer. In this report a beginning is made to breakdown these life cycle costs in several elements in order to reduce the complexity. The following two recommendations are made concerning these costs.

Research on life cycle cost data to elaborate the cost calculator

It should be wise to start research projects to collect and document more detailed LCC data to exploit the benefits of LCC calculations. The percentages of the capex as integrated in the current version of the calculator may be replaced by costs based on separate components (just like the capex). Cooperation with an airport to collect data and to find new correlations is advised. Besides, these new correlations could offer the opportunity to make dynamic cost calculations valuable. An example of such a dynamic calculation based on the results of a simulation run, is calculating failure costs by distinction of maintenance personnel cost and costs related to bags that do not fly with the passenger they belong to (too late for the aircrafts' departure).

Extension of the design choices justification tool

During the final evaluation of the design choices justification tool, an Area manager placed a remark regarding the financing of a BHS. The tool only involves the costs that are related to the BHS, not the way these costs are financed. Vanderlande Industries is advised to start research on the relevance of this aspect and on how to implement this in the tool.

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Public library

Sales Reference Database

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Appendices

Appendix A: Vanderlande Industries, the company

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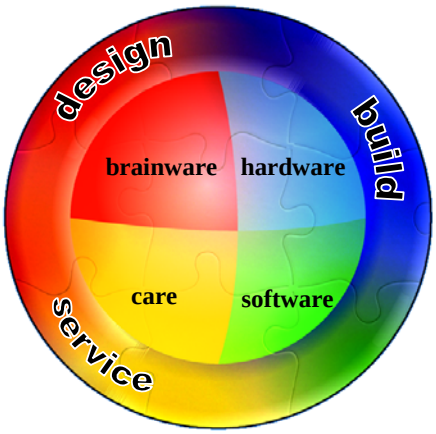
Appendix A: Vanderlande Industries, the company

In this appendix, Vanderlande Industries (VI) will be introduced by describing the company's profile and giving a brief overview of the company's history. After that the organisational structure will be explained.

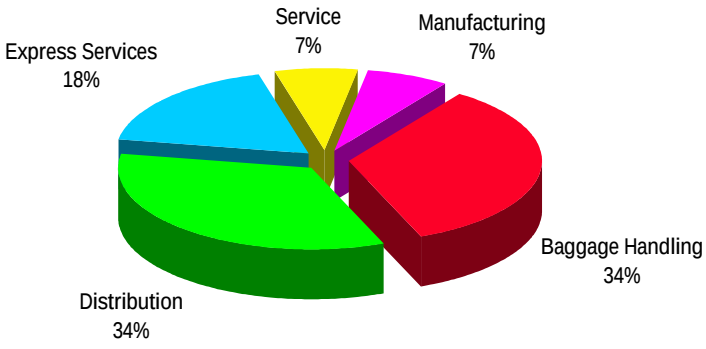
Profile

Vanderlande Industries is an international company that provides automated material handling systems. The company designs and implements tailor-made solutions and strives an integrated system approach (see figure A.1) .



The company's head office is based in Veghel, The Netherlands. It incorporates design, engineering, test and production facilities. Subsidiaries can be found in France, Spain, Germany, Great Britain, Hong Kong, South Africa and the U.S.A. Besides these so-called Customer Centres, there are several agents located all over the world, coordinated from the head office by the VI International Group.

Figure A.1. Integrated syste m approach of Vanderlande Industries.



The clients of Vanderlande Industries can be found in the areas Warehousing and Distribution, Baggage Handling Systems, Express Services Industry and Manufacturing Industry (figure A.2) [VI Public Library, 2001]. This report is about Baggage Handling Systems at airports.

Figure A.2. Percentage of new orders per business area (1997-2001, excluding UPS contract).

History

In 1949 the Industry and Trading Company E. van der Lande was established in Veghel, The Netherlands. At that time, the company was aimed at weaving looms and other machinery for the textile industry. Soon the emphasis was put on material handling systems and the name changed to "Machinefabriek E. van der Lande".

A joint venture was established with Rapistan Inc. in 1963 and the name became "Rapistan Lande". The company became the exclusive licensee of the Rapistan products for The Netherlands, Belgium and Luxembourg. Because of this partnership, the company grew and the first Customer Centres were founded throughout Europe. Since 1986 Vanderlande Industries also founded Customer Centres in Hong Kong, South Africa and the U.S.A. In 1988 the company's name became "Vanderlande Industries". In addition, GamBit GmbH, a German software company specialised in Warehouse Management Systems, was integrated into the group in 1997.

Organisational structure

Figure A.3 shows the organisation chart of Vanderlande Industries. The organisation can be divided into four branches. The departments in the Operations branch work directly on projects, while the Group Activities departments have a more supporting task within these projects. The other two branches are the Customer Centres in a European and a non-European branch (Developing markets).

This master thesis project is executed on authority of the Systems Group (emphasised with a bold border in figure A.3), which is part of the supporting department Group Activities. The Systems Group provides technical and commercial support to Customer Centres and Operations in developing system solutions for customers. The assistance takes place in both the pre-contract phase and the execution phase on issues as design, training, simulation, pricing and presenting ideas to customers. The Systems Group consists of four sub-departments:

- Systems Development
- Simulation
- Proposal Verification & Pricing
- Knowledge Management

These sub-departments are inter-related and together they provide the following services to the organisation:

1. Advice on technical/conceptual issues, go/no-go decisions, pricing, cost/performance of systems or strategic matters
2. Concepting of large complex/special/high-risk projects in the industry groups Baggage Handling, Express Services, In-plant Handling and Assembly based on experience, innovation and alternative solutions
3. Cost estimating and verification of system (sub)prices as well as development of price calculation tools and databases
4. Simulation studies and support
5. Education and training of concepting and pricing activities to Customer Centres through centralisation and actualisation of system knowledge and spreading this knowledge among Customer Centres
6. Analysing market demands within industry groups and providing product solutions for these demands together with R&D
7. Knowledge Management, specifically the facilitation of transfer of system-related know-how within the Sales phase between the Customer Centres

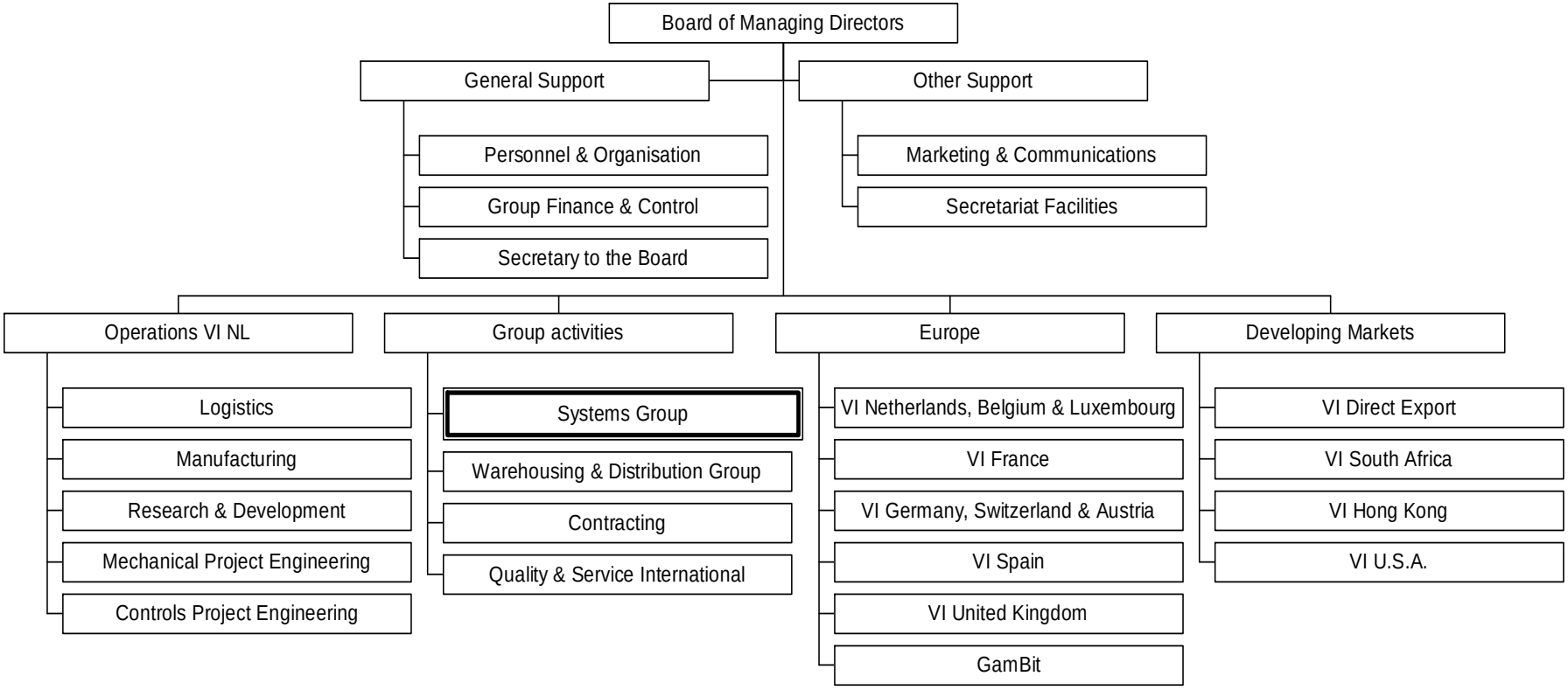


Figure A.3. Organisational chart of Vanderlande Industries

Appendix B: Interaction between a BHS and its environment

Figure B.1 illustrates the interaction of an installed BHS with its environment. The BHS interacts with the bags, as well as with employees, the passengers and several information systems.

The Departures Control System (DCS) communicates with other airports and is controlled by the International Air Transport association (IATA). When a bag is checked-in, the BHS sends a flight registration and the DCS supplies the BHS with a Baggage Source Message (BSM). The BSM contains a unique 10-digit IATA number (License Plate) to identify that bag on all airports. Besides that IATA number the BSM includes the name of the passenger, the flight number(s), the date, the travelling class and the security status of the bag. Based on this information the BHS determines the route of the bag through the system. The information is also sent to the destination airport(s) by a Baggage Transfer Message (BTM).

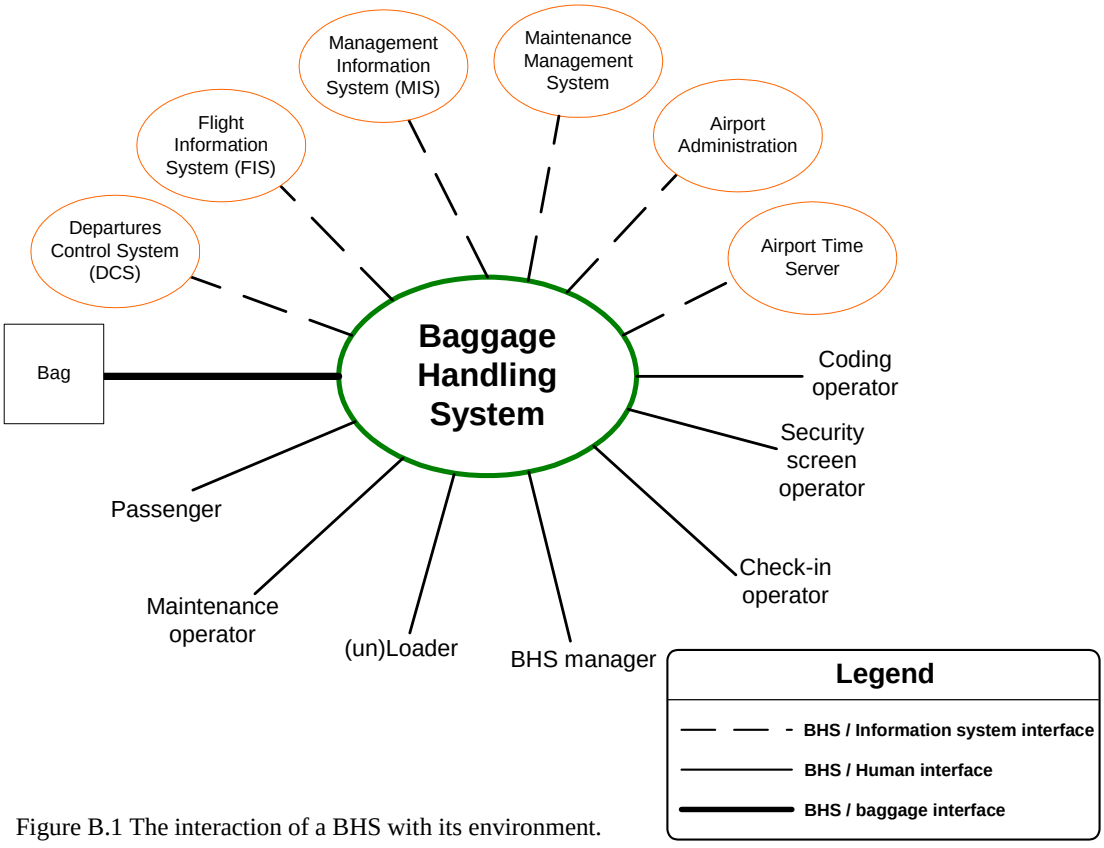


Figure B.1 The interaction of a BHS with its environment.

The Flight Information System (FIS) supplies the BHS with the flight schedule and information about planes that arrive or depart. Based on this information the BHS allocates flights to the baggage collecting points and supplies the routing information of the baggage through the system. The information sent and obtained from the Management Information System (MIS) depends on the requirements of the concerning airport. It

supplies the management with information, such as numbers of bags that are handled in a certain period, that justifies their decisions on high-level airport control. Sometimes there is also a separate Maintenance Management System (MMS) installed to provide the management with information which is necessary to plan maintenance activities, such as the number of operational hours of components.

The Airport Administration bills the airlines for their usage of the BHS. The amount depends on the number of bags handled by the BHS and their weights. Another information system the BHS communicates with, is the Airport Time Server. All the systems working on the airport are connected to this server in order to synchronise all system clocks and guarantee a perfectly timed cooperation.

Looking at the human interfaces, there are passengers and employees who interact with the BHS. The passengers put their bag directly on the system at the check-in desk and re-claim it at their destination (take it off a baggage carrousel). There are several employees working with the BHS. To start, the employee at the check-in desk takes care of the registration, labelling, weighing of the bag and charges it into the system. Another interaction of the system is with the coding and security screening employees. When the baggage has to be screened for security reasons, the most common configuration is a partly automated screening in different levels. After the system screened automatically and “decides” a bag is still suspicious, another level is entered where employees judge the X-ray pictures and open the bag if necessary. Coding baggage is performed to identify the concerning bag (e.g. to determine the route). Often this is a fully or partly manual process with employees scanning a barcode on a bag label with a handheld scanner.

Besides the passengers at the check-in desks who bring baggage into the system, there are other people (and places) who feed the BHS. When a container loaded with transfer baggage (from one plane to another) comes at the airport terminal, loaders take care of the feeding of the system (load the baggage from the container into the BHS). At the different sorting areas unloaders take the baggage off the system into a container (belonging to a flight). Finally, the unloaders take care of the baggage that is out of gauge (OOG, baggage that is not qualified to enter the main baggage stream in the system because of its dimensions) and the non-conveyable baggage (such as a basketball). After it enters the terminal (manually or automatically) this baggage also has to be taken off the system into containers.

The total system has to be maintained in order to perform its function over its whole life cycle. Therefor, maintenance employees interact with the system periodically. Finally, the BHS manager interacts with the system in order to ensure its functionality.

Appendix C: Involved employees of Vanderlande Industries

Vanderlande Industries employees being interviewed during this master thesis

Bruno van Wijngaarden	Warehousing&Distribution Systems engineer
Erik van Rossum	Manager Proposal Verification & Pricing
Friedrich Alexander Olivier	Sales engineer (CC Mönchen-Gladbach)
Harm Koster	Quality & Service International
Henk Geurts	Sales engineer International
Jasmien Mertens	Sales engineer (CC Mönchen-Gladbach)
Marcel Bunkers	Systems engineer
Peter Hoefkens	Manager Simulation / Systems engineer
Rinus Vervoort	CAD engineer
Roy van Putten	Simulation engineer
Ton Koemans	Controls engineer

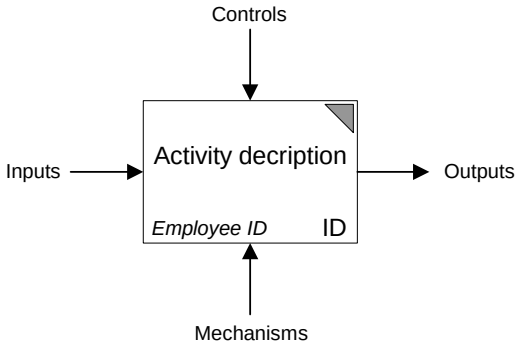
Vanderlande Industries employees (also) involved in the evaluation:

Carlo Boeijen	Sales engineer Benelux
Ernst Iedema	Sales engineer Benelux
Gijs Bartelet	Systems engineer
Hans Bodewes	Manager Systems Group
Jan Graste	Sales engineer Benelux / International
Marnix Rutten	Sales engineer International
Robert van Ree	Sales man Benelux
Roland van den Bergh	Area manager International
Sjouke Tjalsma	Manager Sales engineering International
Toin Aarts	Quality & Service International
Ton van Wieringen	Systems engineer

Appendix D1: IDEF-0 model of the current design functions

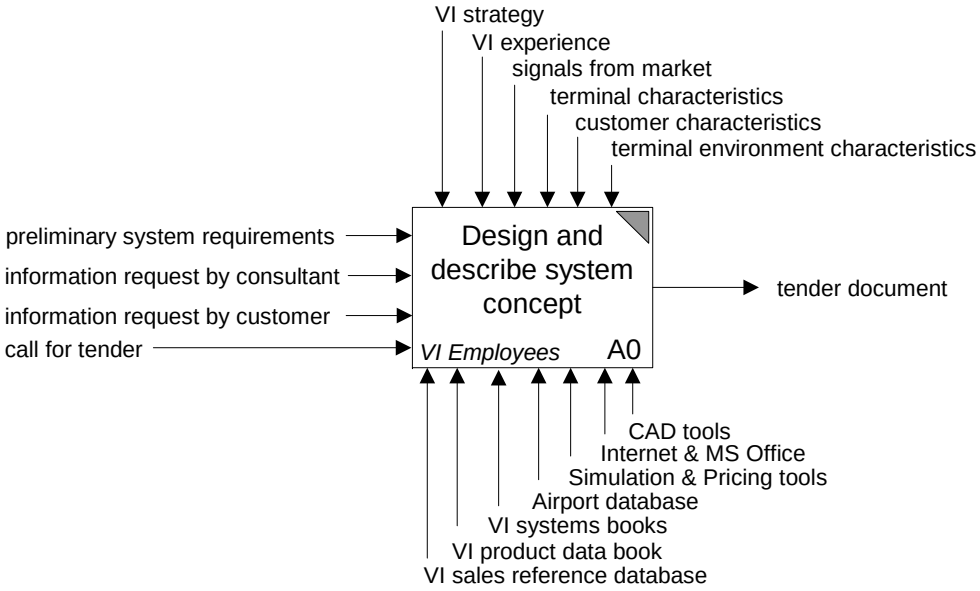
Model explanation

The box contains the name of the function, the ID of the function and the ID of the employee who fulfils this function. If a grey triangle is shown in the upper right corner of the box, the function is further detailed (divided in several functions). The ID of these detailed functions refers hierarchical to the function they were derived from (e.g. A2.4 is derived from A2).

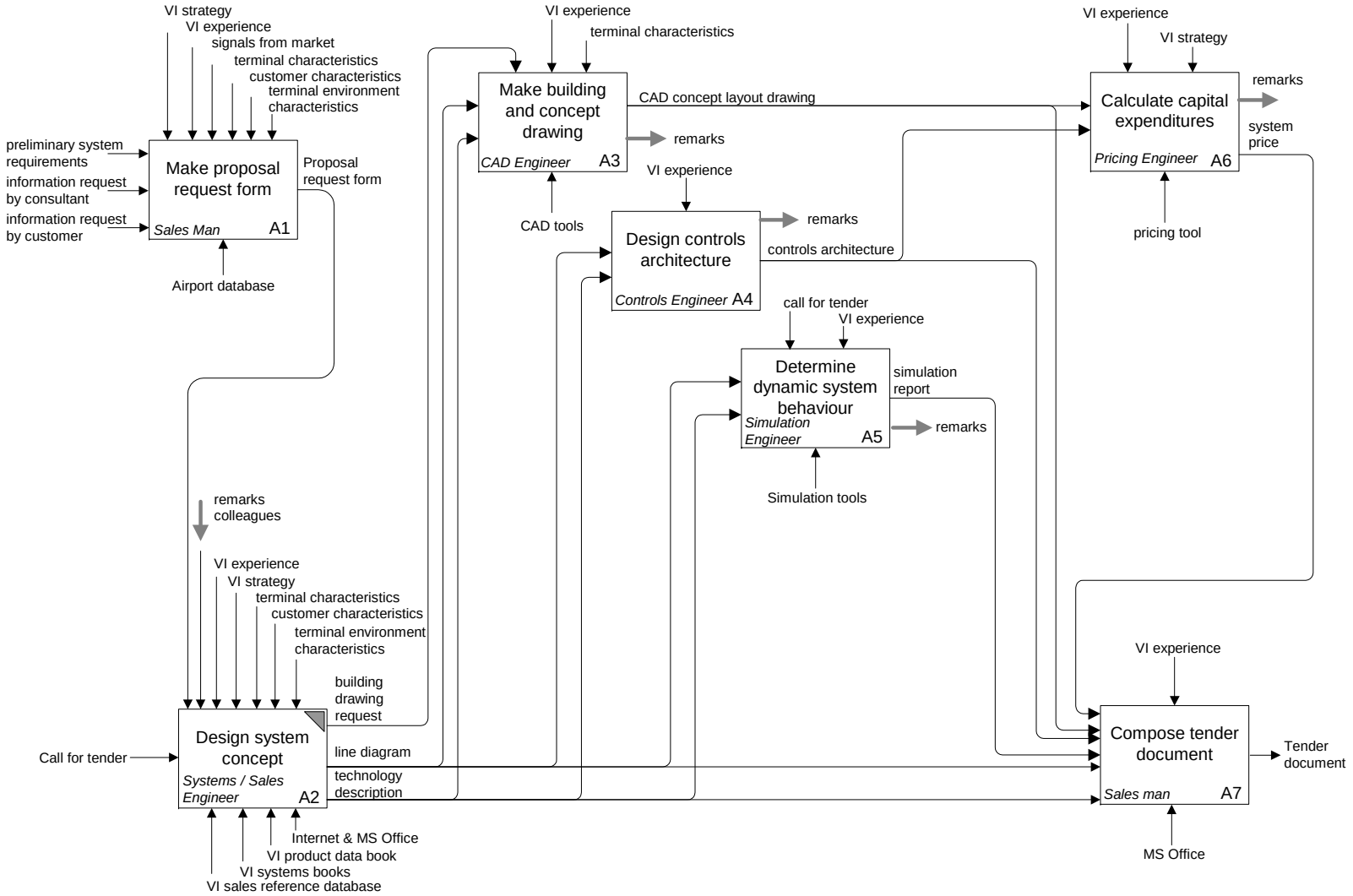


The arrows represent the interfaces of the function with its environment. Input represents the physical products that are processed by the function. Output represents the products of the function. Controls are the “triggers” of the function, the influence the way the function is fulfilled. Finally, the mechanisms represent the required necessities that support the function fulfilment.

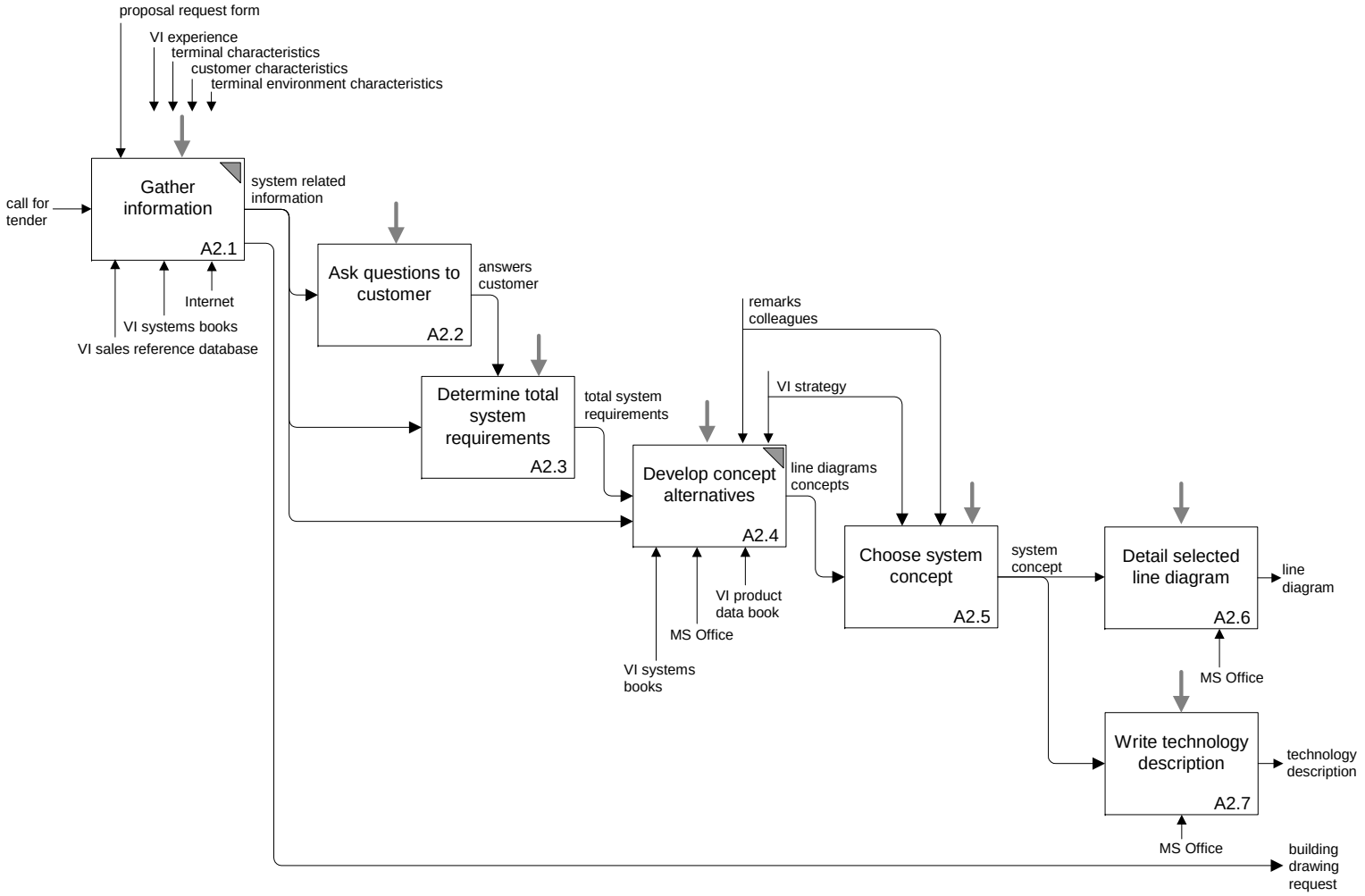
Function “Design and describe system concept” Current situation



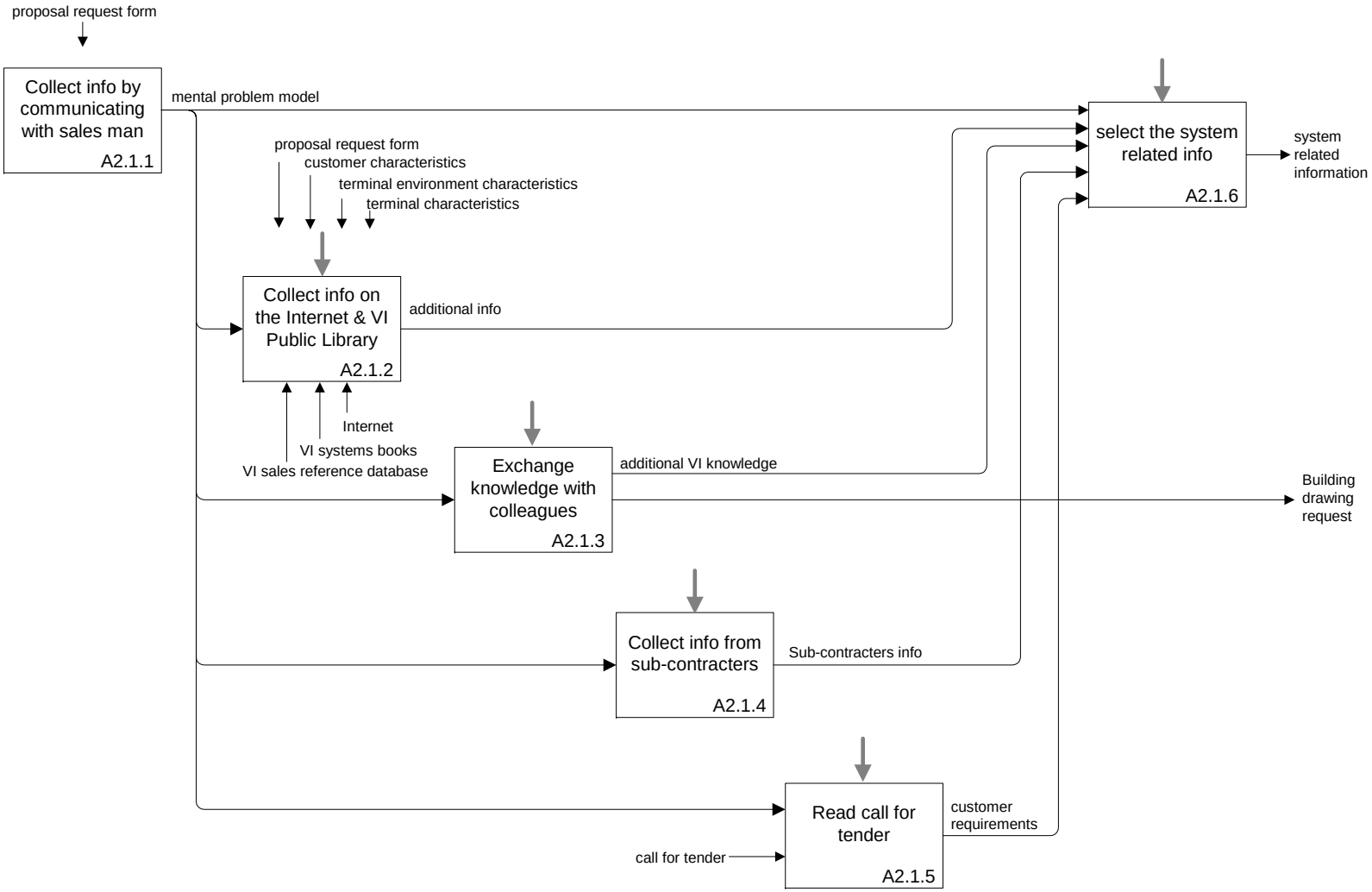
Level A0: Function “Design and describe system concept” Current situation



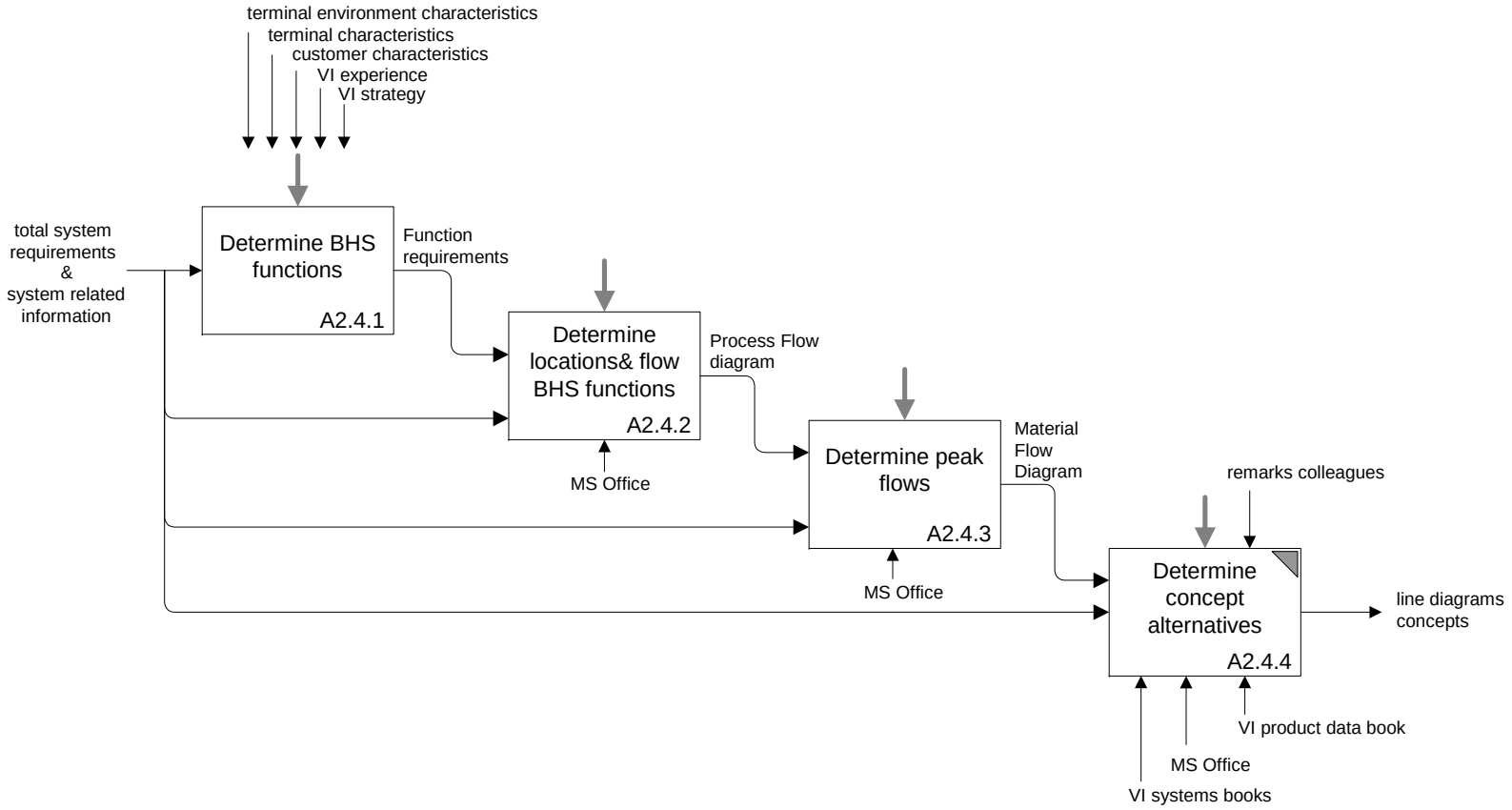
Level A2: Function “Design system concept” Current situation



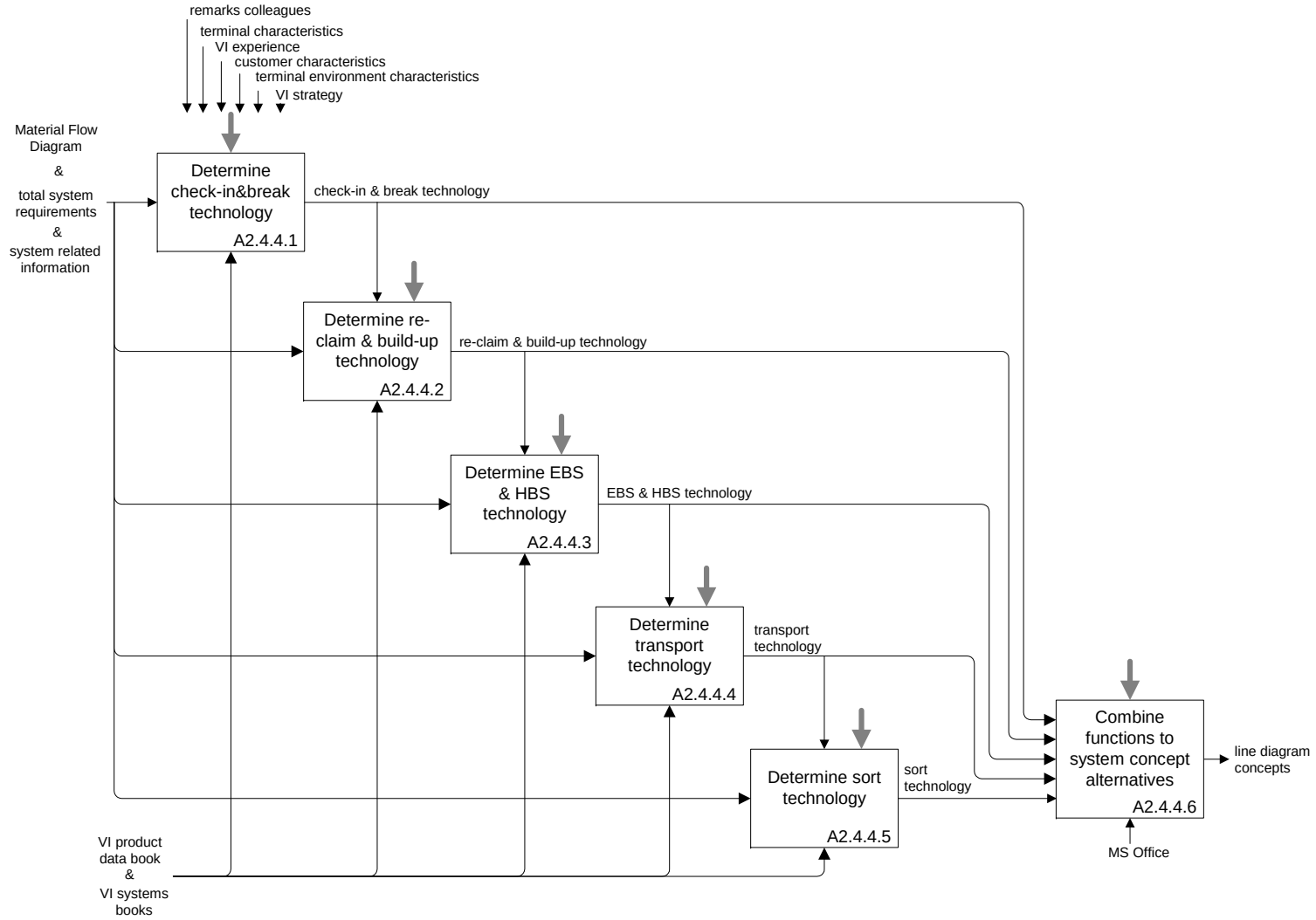
Level A2.1: Function “Gather information” Current situation



Level A2.4: Function “Develop concept alternatives” Current situation

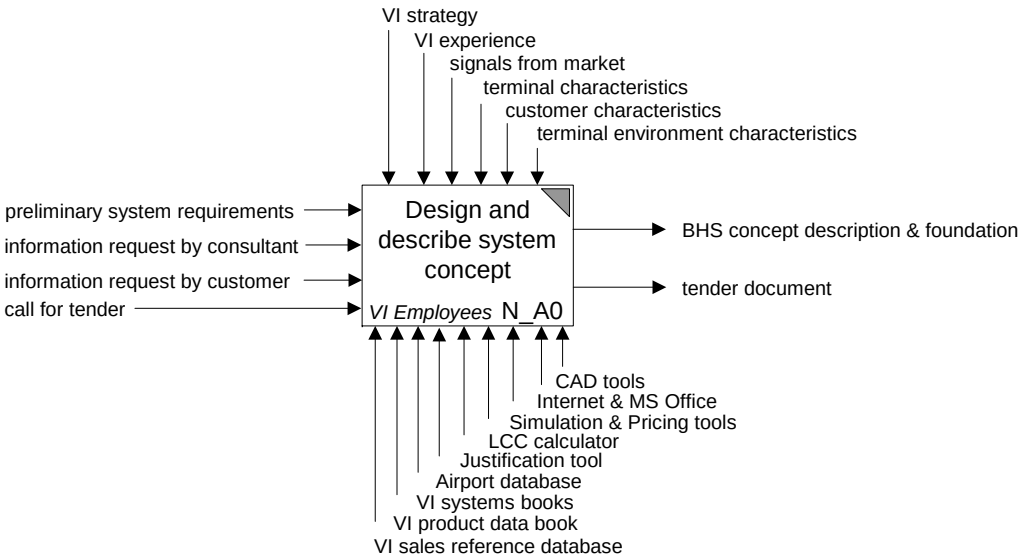


Level A2.4.4: Function “Determine concept alternatives” Current situation

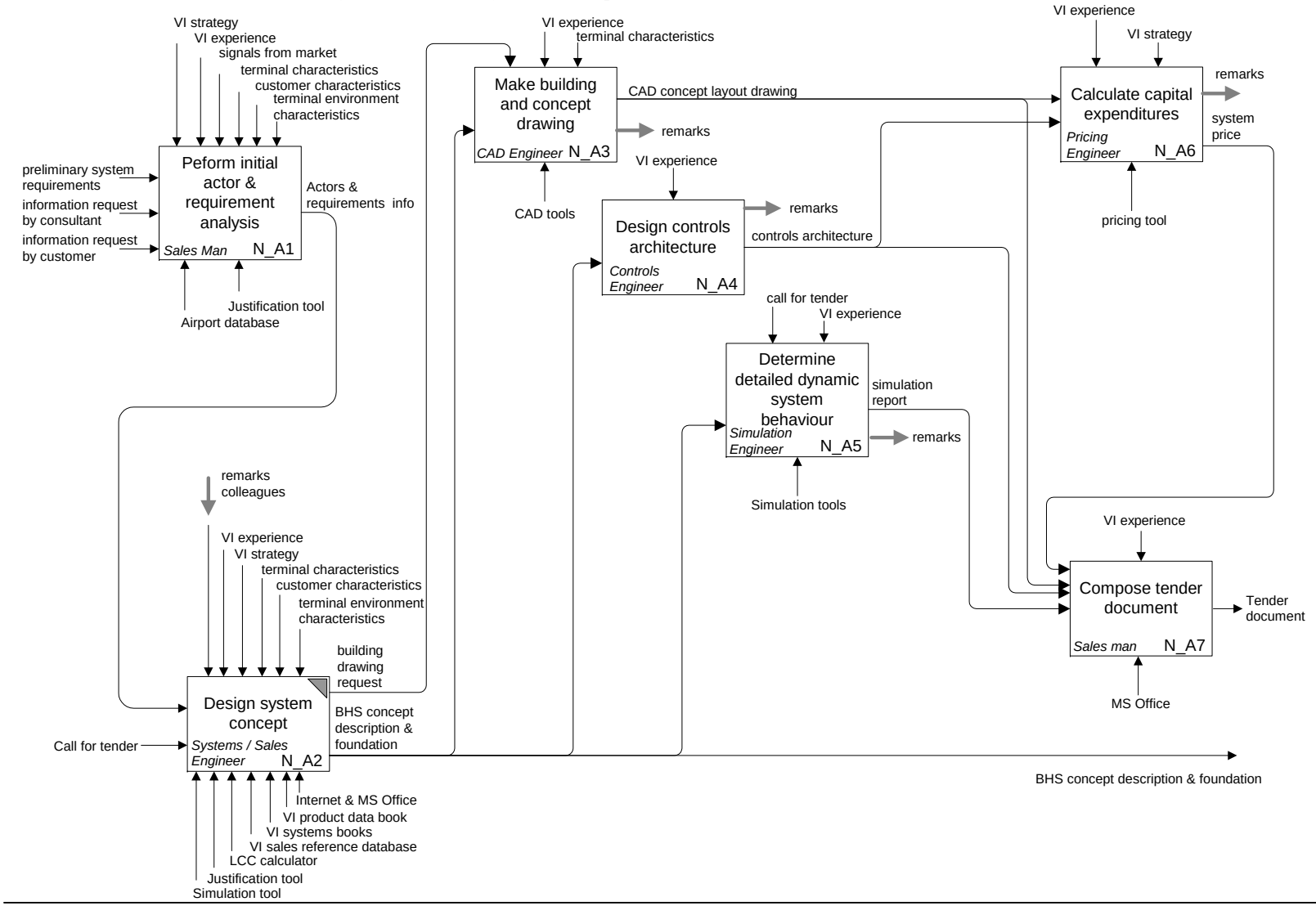


Appendix D2: IDEF-0 model of the new design functions

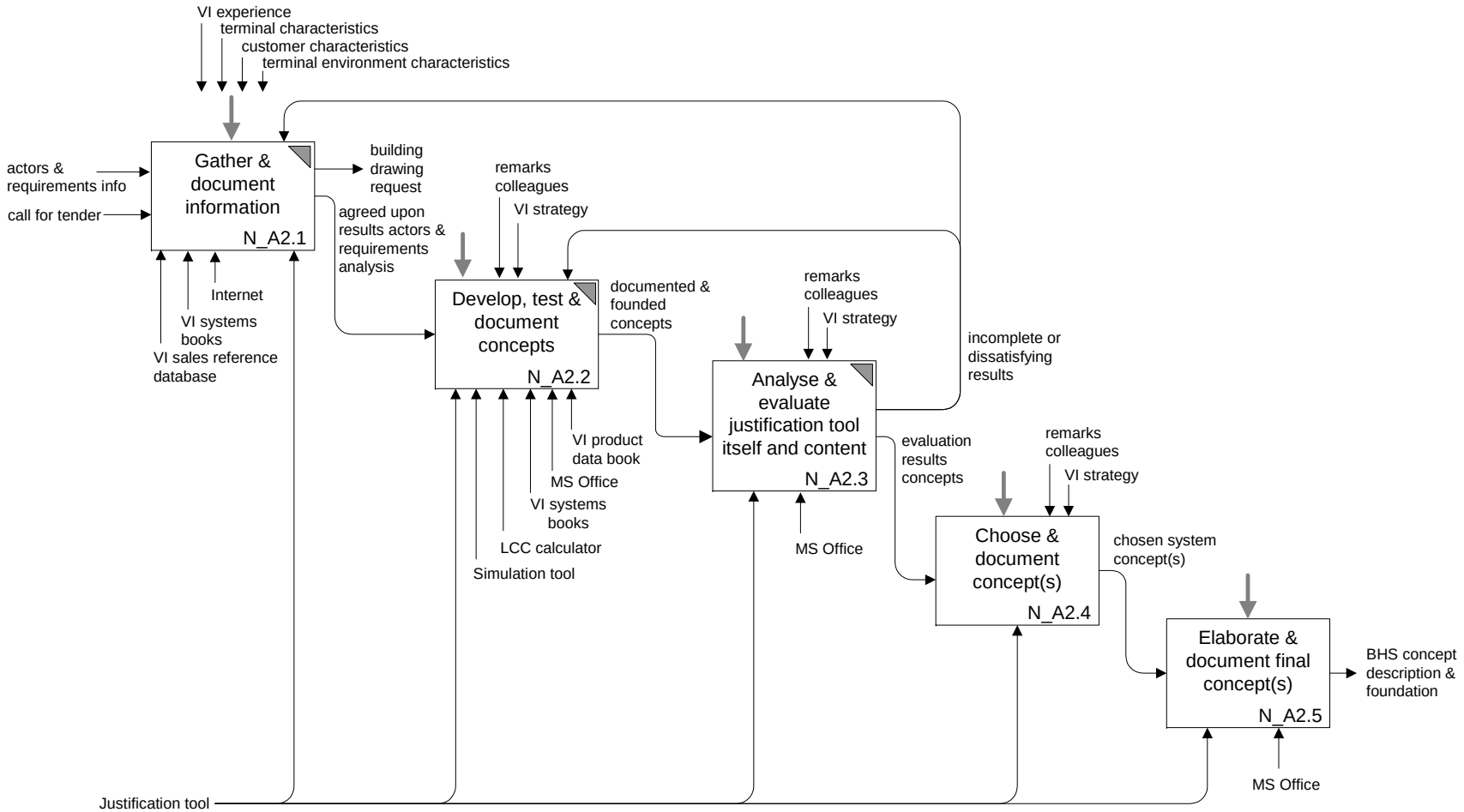
New situation



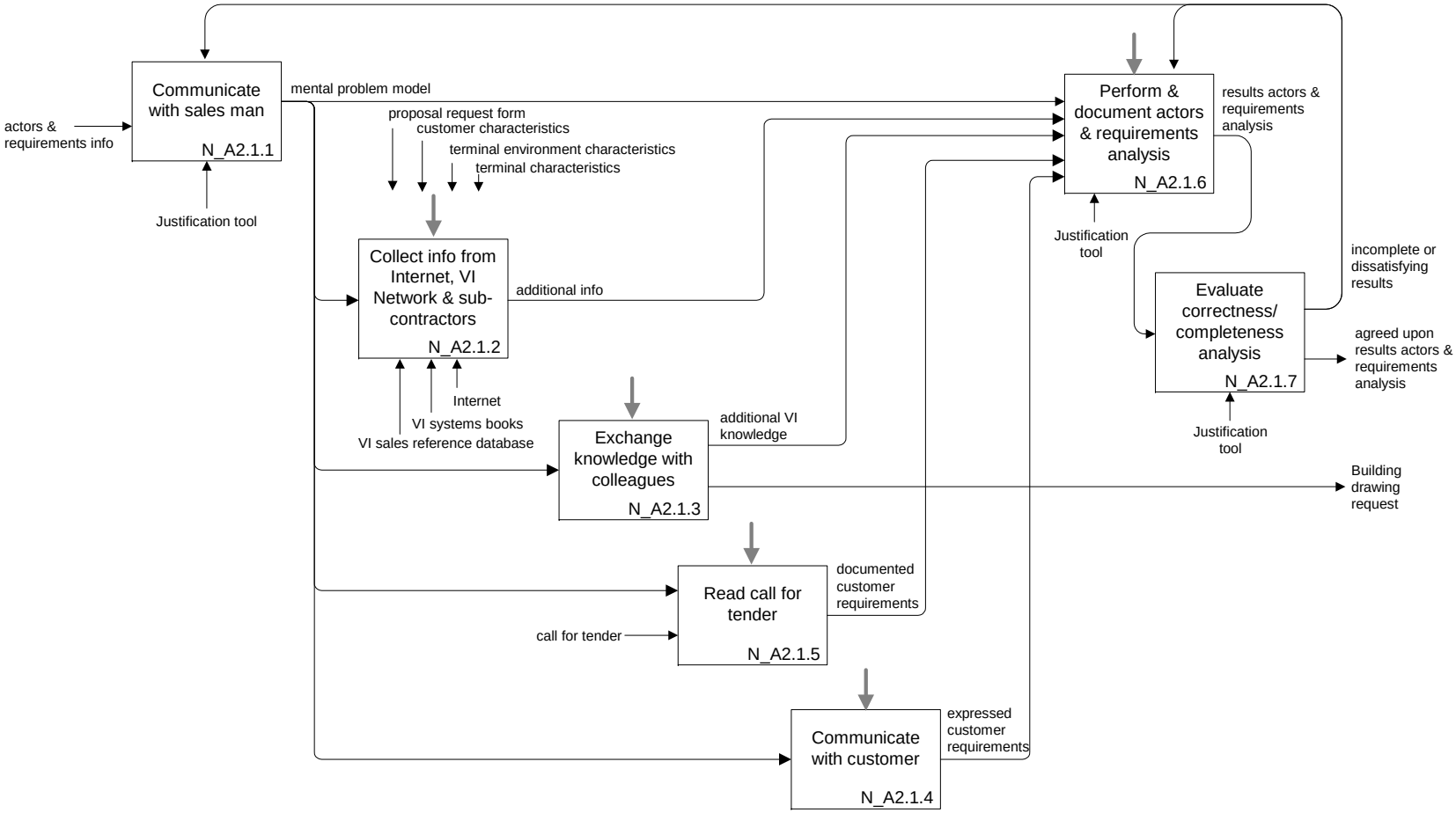
Level N_A0: Function “Design and describe system concept” New situation



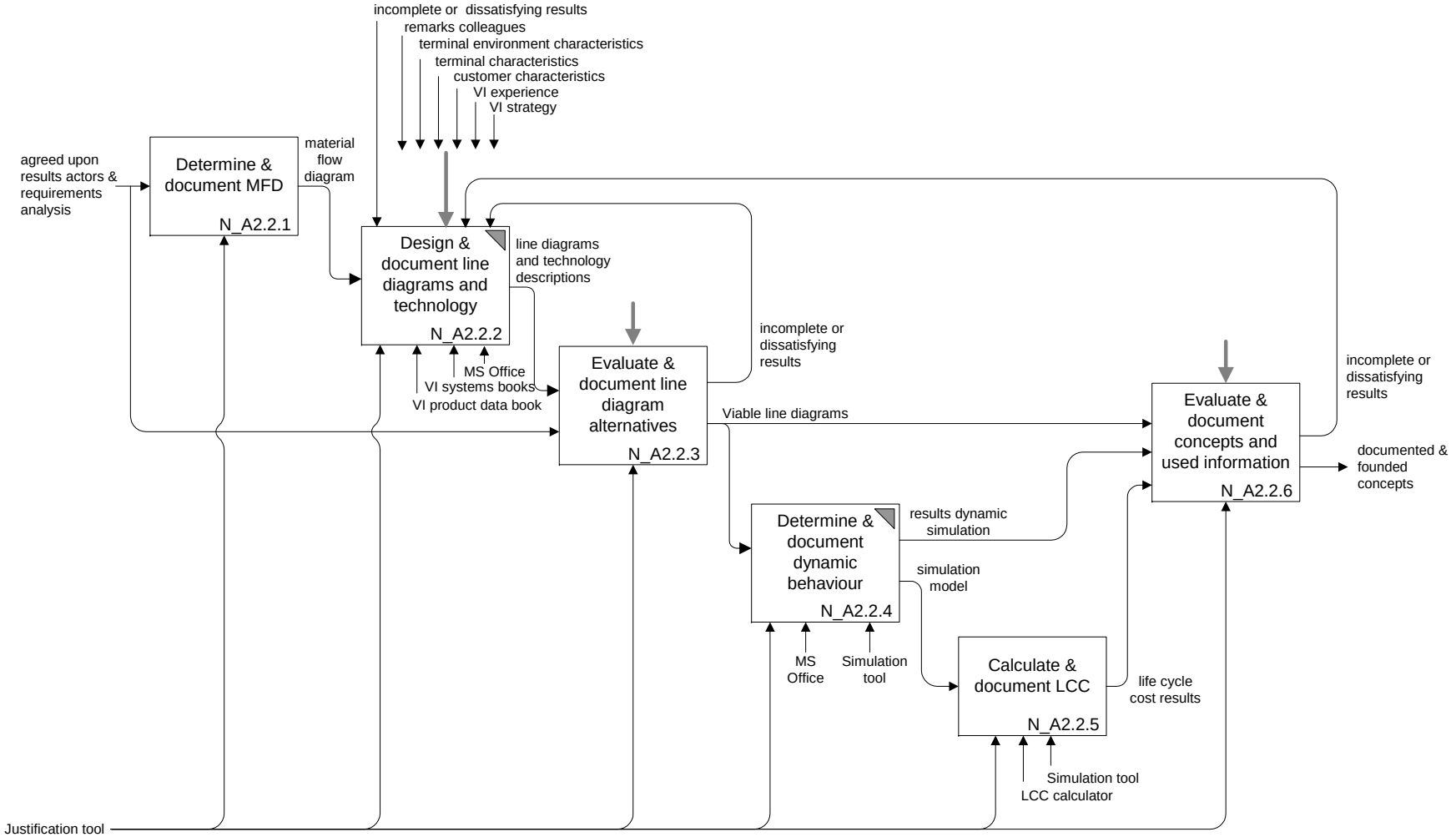
Level N_A2: Function “Design system concept” New situation



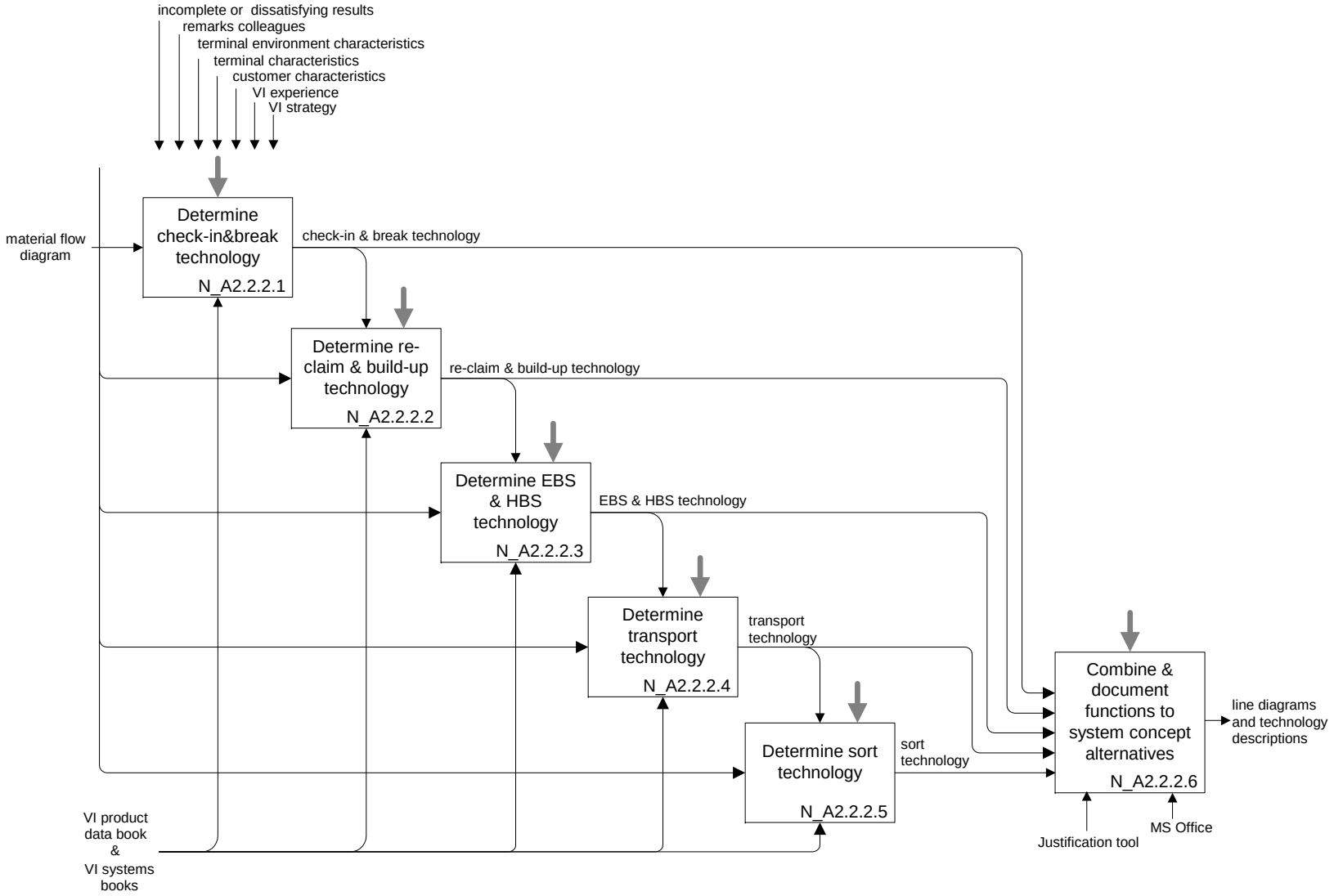
Level N_A2.1: Function “Gather and document information” New situation



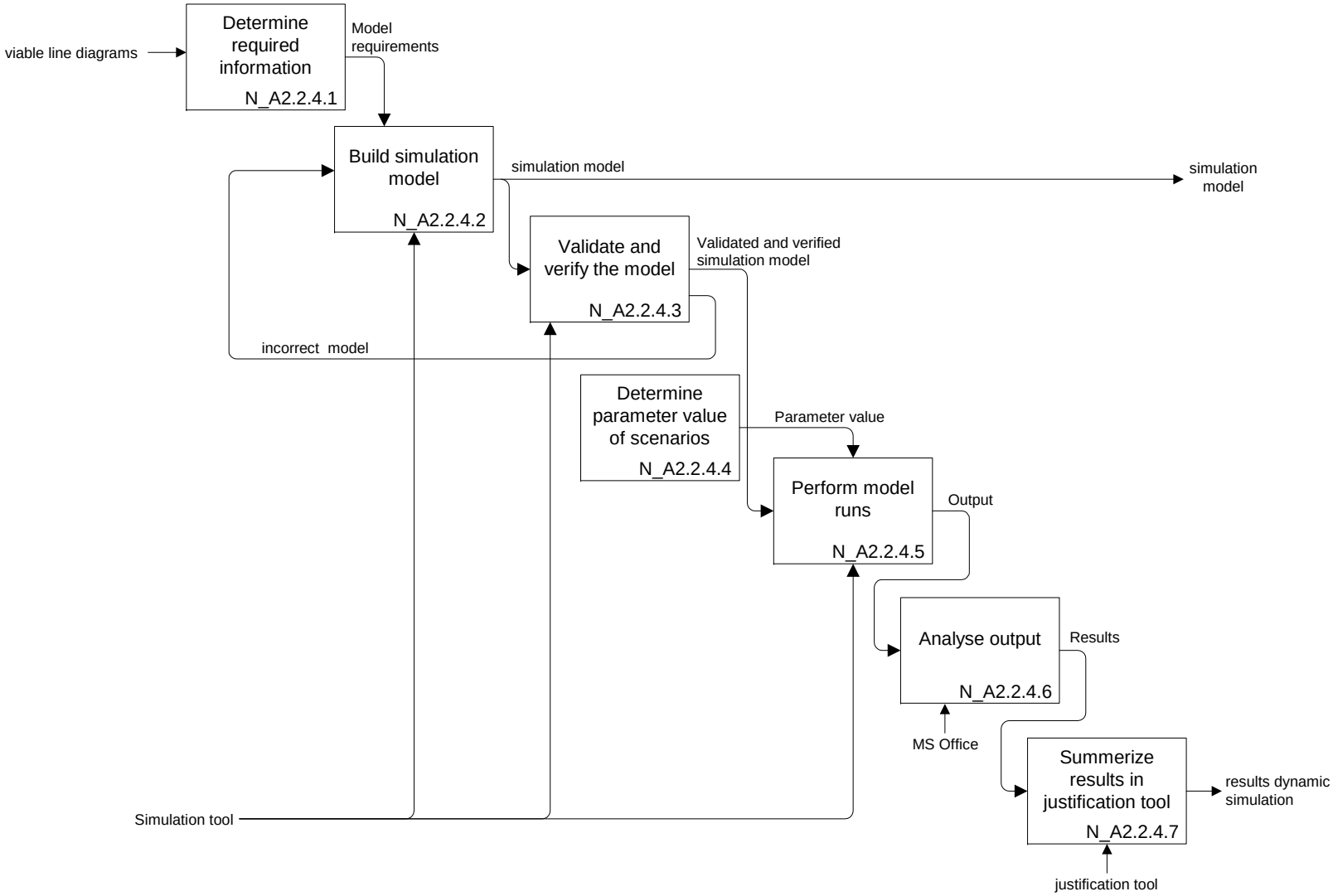
Level N_A2.2: Function “Develop, test and document concepts” New situation



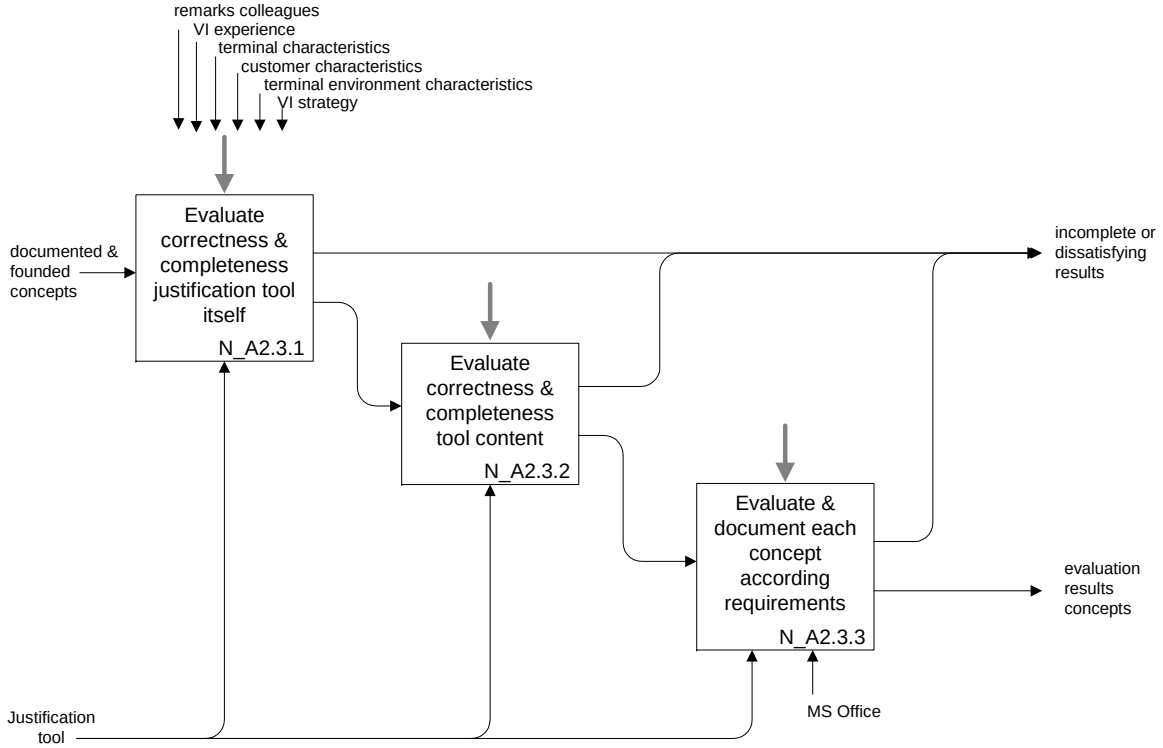
Level N_A2.2.2: Function “Design and document line diagrams and technology” New situation



Level N_A2.2.4: Function “Determine & document dynamic behaviour” New situation



Level N_A2.3: Function “Analyse and evaluate justification tool itself and content” New situation



Appendix E: The design choices justification tool layout

The BHS design choices justification tool exists of a MS Excel document containing five different worksheets named General, Stakeholders, Requirements, Concept and Concept History (excluding the two copies of the Concept worksheet). The General worksheet contains a template for general information (including tool objective, see below) and the Stakeholders worksheet contains information about the customer and the (future) environment of the BHS. The Requirements worksheet offers a template for the total set of requirements on the BHS and the Concept worksheet, contains the template to describe the designed BHS concept. The history of the concepts is documented in the final worksheet. In this appendix the different worksheets are shown and if necessary provided with a brief explanation. To save space some tables are shortened or omitted.

General worksheet

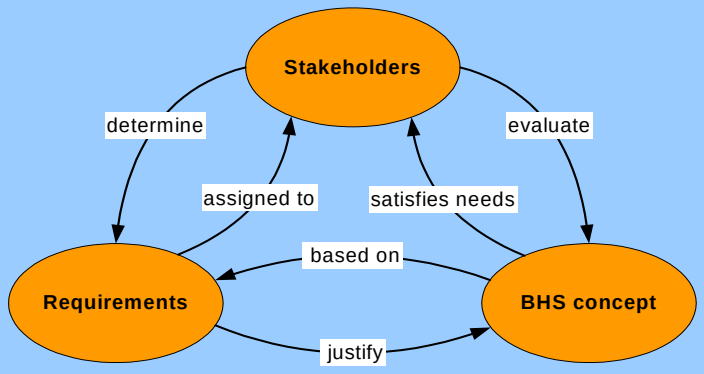
VAN DER LANDE INDUSTRIES

Supporting the design of VI Baggage Handling Systems

Project name	
Customer's organisation name(s)	
Project number *[in accordance with the VI guideline sales document numbering 8.2137.0139.G]*	

Author *[initials]*	**Date** *[dd/mm/yyyy]*	**Reason for revision**

Document objective:
The objective of the tool is to support the VI employees in:
1) Performing and documenting a stakeholders network analysis
2) Eliciting, prioritising and documenting the total set of requirements on the future BHS
3) Objectively founding the designed BHS concepts by documenting each part of the concepts in relations to the requirements that apply to that specific part



Stakeholders worksheet

Stakeholder analysis: the customer and his environment

Document objective:
Enable all involved VI persons to consistently exchange knowledge about the customer's environment, the customer's characteristics, the project approach and project status, in order to determine and communicate the best strategy to be followed.

Content
1 Initial problem description
2 Organisation chart customer
3 Stakeholders
4 Stakeholders' characteristics
5 Stakeholders' objectives and perspectives
6 Stakeholders' means
7 Stakeholders' interdependencies
8 Communication agreements
9 Meetings overview
10 Other communication overview
11 Strategy in stakeholders approach
12 General remarks

1 Initial problem description

[description of the problem with which the customer approaches VI]

Author *[initials]*

Problem description

2 Organisation chart customer

[Organisation chart including names, communication lines]

3 Stakeholders

[Not only those stakeholders that are intentionally selected and activated and thus more closely involved in the design process, but also the indirect involved stakeholders, who can play an important role (such as blocking or promoting a solution). Think of:
Airport authorities
Airport employees (levels: management, operations, maintenance, contracting, finance, etc.)
Airport operators
Main contractors
Consultants
Airlines
Architects
Project managers (external)
Handling agent (independent party with core business baggage handling, e.g. OGDEN)
Competitors
Agents working for VI or other stakeholders
Partners (mostly Controls)
Sub-contractors
Security stakeholder
Shop owners
Government (different levels, EU, National, District, Local)
Passengers
Media
Commercial organisations with influence (for instance large customer of airport).
Agents
VI colleagues (management, Salesmen, Area managers, Sales engineers, Systems engineers, Simulation engineers, CAD engineers, Controls engineers, Contracting, Mechanical engineers, R&D engineers, VI project manager, Purchasing, Planning, Pricing, Customer Centres)
Etc.]

ID (initals)	Organisation name	Department	Person	Function	Telephone & e-mail
[initials]	*[name]*	*[department name]*	*[person's name]*	*[function name]*	*[telephonenr. & e-mailaddress*
MF	FlyHappy Airport	Operations	Mike Flight	Manager Operations	Flight@FlyHap.com

4 Stakeholders' characteristics

[Comments about the different stakeholders that should be shared with the VI colleagues]

Author	Stake-holder	Date	Comment
[initials]	*[initials]*	*[dd/mm/yyyy]*	*[good relations with who (VI employees, consultants, competitors, etc.), earlier experiences with VI, level of BHS knowledge, conventional/in front with high-tech, etc.]*

5 Stakeholders' objectives and perspectives

[What are the fundamental objectives (stabile in time, mostly abstractly formulated) of the stakeholder and what are the concrete objectives (concrete issues) for this project. And what is the perception of the problem and solution of the stakeholder, depending on e.g. the cultural background, position, ambition, fundamental objectives, available vocabulary (what can be discussed) and individual frame of reference (selective perception)]

Stake-holder	Date	Fundamental objectives	Problem and solution perception	Concrete objectives
[initials]	*[dd/mm/yyyy]*	*[mission e.g. continuation, profit, good name, trust customers, increase quality systems, increase market share]*	*[describe the problem and possible solution directions from the stakeholders view point]*	*[objectives in this project e.g. getting awarded with commission, decreasing the nr. of mis-connected bags, etc.]*

6 Stakeholders' means

[What means, both formal and informal, can the stakeholder deploy in order to reach the objectives (technical, juridical, social or economical). And is the stakeholder a formal, informal or no decisionmaker in the project?]

Stake-holder	Formal decision power	Informal decision power	Date	Means
[initials]	*[yes / no]*	*[yes / no]*	*[dd/mm/yyyy]*	*[such as provide information, men power, knowledge, funds or set in jurisdiction, authority, relations, persuasiveness, exercise a veto, lodge a notice of objection, status, compulsion, blackmail, etc.]*

7 Stakeholders' interdependencies

[In what way are the involved stakeholders interdependent, e.g. on resources, information, relations (both formal and informal) and positions of power]

Stake-holder	Stake-holder	Date	Nature of interdependency
[initials]	*[initials]*	*[dd/mm/yyyy]*	*[e.g. financially, information gathering, possible future cooperation, formal or informal relations, authority]*

8 Communication agreements

[What are the agreements made regarding communication]

VI	Stake-holder	Date	Agreements	Comments
[initials]	*[initials]*	*[dd/mm/yyyy]*	*[Contact persons, addresses, contact frequency, deadlines intermediary products,*	*[changes, exceptions, etc.]*

9 Meetings overview

[Who spoke to whom, when, what were the subjects and the results]

VI	Stake-holder	Date	Subjects	Results	References
[initials]	*[initials]*	*[dd/mm/yyyy]*	*[subjects of meeting]*	*[main results]*	*[minutes of meeting document name]*

10 Other communication overview

[From who to who what were the subjects and the results]

VI	Stake-holder	Date	Subjects	Results	References
[initials]	*[initials]*	*[dd/mm/yyyy]*	*[subjects of communication]*	*[main results]*	*[e-mail, letter, document name]*

11 Strategy in stakeholders approach

[Author, date, stakeholder, approach of stakeholder]

Author	Date	Stake-holder	Approach
[initials]	*[dd/mm/yyyy]*	*[initials]*	*[Technical/Economical/Managerial/Communicational measures: such as involve in process, emphasise new technology, emphasise other project references, emphasise proven technology, emphasise good relation, emphasise extendability, emphasise LCC, emphasise low noise, offer more then one concept options, offer certain quality/price balance, emphasise or keep silent about certain risks, etc.]*

12 General remarks

[Author, date and remark]

Author	Date	Remark
[initials]	*[dd/mm/yyyy]*	*[all remarks about the sales process that can not be classified in one of the previous tables]*

Requirements worksheet

The characters of the requirement or constraint ID code refer to:

FT: Functionality or technology requirement

CS: ConStraint

SR: Specific Requirement

PR: Procedural Requirement

The table as shown for the check-in functionality is repeated for transport, sorting, make-up, break, HBS, EBS, controls, consolidation and other.

Requirements documentation

Document objective:
Support the process of complete and consistently requirements elicitation and documentation.

Content
1 Introduction
2 General functionality and technology requirements
3 Constraints
4 Specific BHS requirements
5 Procedural requirements

1 Introduction

The following characteristics can be used to identify real, quality requirements:

Complete	nothing is missing (no "to be determined") and all conditions under which the requirements applies stated
Consistent	does not conflict with other requirements
Correct	accurately states a customer need
Feasible	can be implemented within known constraints
Modifiable	can be easily changed, with history, when necessary
Necessary	documents something customer really needs
Prioritised	ranked as to importance of inclusion in product
Testable	possible to ensure that the requirement is met
Traceable	origin (source) of requirements known
Unambiguous	has only one possible meaning/interpretation

Note that it is possible that the customer doesn't realise the total set of his requirements in the first phase of a project. Talking with the customer about the aspects of a BHS, pointing out the results for certain implementations and iteration in the requirements elicitation process helps determine the real set of requirements. By communicating it can also become clear that the constraints as set up at the start of the project will change. Filling in this template is a iterative process.

The ID Code is composed as follows:
Example: SR2.4
SR : Requirement characteristics, possibilities: FT (Functionality or Technology requirement), CS (Constraint), SR (Specific Requirement), PR (Procedural Requirement)
2.4 : Second section, fourth requirement
When requirements are changed, the original version must be kept. By inserting a new row just below the original requirement and adding an extra number behind the code, the history is documented.
SR2.4.2: Specific Requirement, second section, fourth requirement and version two.

The sources as mentioned for each requirement in this document ("assigned to") refer to the stakeholders, mentioned in the worksheet named "Stakeholders".

2 General functionality and technology requirements

[Keep the entered requirements in accordance with the characteristics mentioned in the introduction]

2.1 Check-In functionality and technology

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Check-in functionality required? If yes, certain technology required?]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yyyy]*	*[further details and possible changes]*
BB	FT1.1	Walk-through check-in desks including elevators	MF	Mandatory	High	16-5-2002	MF saw walk-through check-in on Köln-Bonn Airport
	FT1.2						
	FT1.3						
	FT1.4						
	FT1.5						

3 Constraints

The limitations to the solution scope.

3.1 Existing BHS constraints

[dismantle, integrate or reuse existing BHS (sub-)systems or controls]

Author	Constr. ID	Description	Assigned to	Rigidity level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Unambigious and complete constraint description]*	*[initials]*	*[fixed / flexibel]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	CS1.1						
	CS1.2						
	CS1.3						
	CS1.4						
	CS1.5						

3.2 Knowledge constraints

[Level of technical know-how of e.g. the handling, controls and maintenance employees working with the BHS]

Author	Constr. ID	Description	Assigned to	Rigidity level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Unambigious and complete constraint description]*	*[initials]*	*[fixed / flexibel]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	CS2.1						
	CS2.2						
	CS2.3						
	CS2.4						
	CS2.5						

3.3 Terminal building constraints

[Possible relevant factors:
Availability of space
Column grid
Free height
Building construction
Power supply
Distances
Etc.]

Author	Constr. ID	Description	Assigned to	Rigidity level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Unambigious and complete constraint description]*	*[initials]*	*[fixed / flexibel]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	CS3.1						
	CS3.2						
	CS3.3						
	CS3.4						
	CS3.5						

3.4 Environmental constraints

[Possible relevant factors:
Political relations
Local wages
Unions
Employment figures
Local philosophy towards security and employment
Working conditions legislation
Legislation on competition
Climatic influences (moisture, temperature, wind, sand, precipitation)
BHS market situation
Reliability energy supply
Media attention
Fire hazard regulations
Developments in the air transport market
Economic development
Infrastructure around airport (levels)
Type of airplanes
Type of transport between build-up and airplane
Etc.]

Author	Constr. ID	Description	Assigned to	Rigidity level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Unambigious and complete constraint description]*	*[initials]*	*[fixed / flexibel]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	CS4.1						
	CS4.2						
	CS4.3						

3.5 Vanderlande Industries constraints

[Possible relevant factors:
Relation with relevant stakeholders
Guarantee philosophy
Engineering and delivery times
Terms and conditions for delivery
Performance-margins level of acceptance
Quality/uniqueness level of concept
Etc.]

Author	Constr. ID	Description	Assigned to	Rigidity level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Unambigious and complete constraint description]*	*[initials]*	*[fixed / flexibel]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	CS5.1						
	CS5.2						
	CS5.3						

3.6 Competition constraints

[Possible relevant factors:
Number of competitors
Reputation competitors
Relationships between competitors and relevant stakeholders
Etc.]

Author	Constr. ID	Description	Assigned to	Rigidity level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Unambigious and complete constraint description]*	*[initials]*	*[fixed / flexibel]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	CS6.1						
	CS6.2						
	CS6.3						

4 Specific BHS requirements

4.1 Flow requirements

[possible relevant factors:
Baggage split (non-conveyable, OOG)
Bag characteristics (dimensions, weights)
Expected passenger flow (peaks/average/spread, originating, terminating, transfer)
Expected baggage flow (peaks/average, originating, terminating, transfer)
Flight data (aircraft departure and arrival during a peak day, number and type of airplanes, seats per aircraft, aircraft occupancy (loading factor), average pieces of bags per passenger beside hand-held baggage)
Originating flow (arrival pattern of passengers at check-in desks)
Arrival flow (transfer ratio and transfer matrix (what are the destinations of transfer baggage)
Specific flow (% of check-in and transfer baggage that can not be read automatically, working rates of manual coding operations, screening rates and the % of bags that are accepted after each subsequent level of screening, storage strategies, storage volumes and required storage retrieval flows)
Distinction between intercontinental / domestic passengers
Ratio of "high priority" baggage (late check-in or transfer baggage)
Equipment flow capacity: volume throughput per component
Etc.]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	SR1.1						
	SR1.2						
	SR1.3						

4.2 Operation time requirements

[Possible requirement factors are the number of operational years, days per year, hours per day and expected occupation of equipment during operation]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	SR2.1						
	SR2.2						
	SR2.3						

4.3 Performance requirements

[Possible relevant factors:
In-system times (divided in different flows, divided in different processes such as transport and storage)
Maximum connection times (MCT)
Waiting times passengers at check-in desks (max, average, spread)
Waiting times operators (loaders, unloaders, identification, screener, etc.)
Utilisation operators (maximum, average, standard deviation)
Reliability (% bags which needed manual intervention to get through the system, % bags not travelling on same flight as passenger, % damaged bags, mean time between failure, maximum time between failure)
Availability (malfunction, times (unattended, standby, operating, in service, downtime, see also maintainability)
Component process times
Performance guarantees (agreements about who takes the risk in e.g. throughput, required men power and components quality)
Etc.]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	SR3.1						
	SR3.2						
	SR3.3						

4.4 Redundancy requirements

[Possible relevant factors:
What-if-situations (scenarios, what happens and what is the impact on the factors relevant to the requirements)
Remaining capacity and functionality in failure cases
Re-routing possibilities
Etc.]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	SR4.1						
	SR4.2						
	SR4.3						

4.5 Flexibility requirements

[Possible relevant factors:
Modular concept or different alternatives
Extendibility (future extensions possible)
Phaseability (installations in phases possible without operational interruption)
System functionality
Down-gradeability (system used only partly in quiet hours)
Etc.]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	SR5.1						
	SR5.2						
	SR5.3						

4.6 Conveyability requirements

[Possible relevant factors:
Straight lines (few curves allowed)
Minimum points of transfer
Minimal slopes
Tubbing of raw baggage
Handling smoothness
Etc.]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	SR6.1						
	SR6.2						
	SR6.3						

4.7 Controllability requirements

[Possible relevant factors:
Tracking and tracing
Status information (operational, continuous information)
Management reporting/statistics (what data at what moment in what form)
Interfaces with existing software
Failure modes
Start-up after emergency-stop
Software up-gradeability
RFID (Radio Frequency Identification)
Routing and balancing
Peak-shaving
Etc.]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	SR7.1						
	SR7.2						
	SR7.3						

4.8 Maintainability requirements

[Possible relevant factors:
Maximum TTR (time to repair) or MTTR (mean time to repair)
No or few special tools required
Reduced spare parts use
Maintenance control systems
Training (operational capability)
(International) back-up systems
Etc.]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	SR8.1						
	SR8.2						
	SR8.3						

4.9 Safety requirements

[Possible relevant factors:
Emergency stops
Danger detection
Fencing
Fire protection (not only in a technical way, but also in a "human" way e.g. fire escape routes operators)
Risk Analysis (what can go wrong, what did we do about it)
Etc.]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	SR9.1						
	SR9.2						
	SR9.3						

4.10 Ergonomics requirements

[Possible relevant factors:
Easy operation
Noise level
Physical load
Etc.]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	SR10.1						
	SR10.2						
	SR10.3						

4.11 Life cycle cost requirements

[Possible relevant factors:
Capital expenditures budget
Organisations and Management set up expenditures budget
Operational expenditures budget
Maintenance expenditures budget]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yy yy]*	*[further details and possible changes]*
	SR11.1						
	SR11.2						
	SR11.3						

5 Procedural requirements

[Possible relevant factors:
Tender document content and layout
Presentations or reports (intermediary)
Actions in certain periods of time (planning)
Open competition legislation
Etc.]

Author	Requirm. ID	Description	Assigned to	Compliance level	VI priority	Date	Comments
[initials]	*[ID code]*	*[Requirement description according the characteristics mentioned in the introduction]*	*[initials]*	*[mandatory / guidance]*	*[high / medium / low]*	*[dd/mm/yyyy]*	*[further details and possible changes]*
	PR1.1						
	PR1.2						
	PR1.3						

Concept worksheet

BHS concept documentation

Document objective:
Support the complete documentation, evaluation and justification of designed BHS concepts.

Content
1 Concept layout
2 Technology specification
3 Cost effectiveness
4 References

1 Concept layout

1.1 Material flow diagram
[add MFD from e.g. MS Visio by copy&paste]

Author	Comments
[initials]	*[Comments regarding the MFD]*

[Requirements and/or constraints concerning this MFD concept]

Requirem. / constr.	Description	Compliance level	VI Priority	Assigned to	Organsiation	Person
[ID code]	*[Requirement / constraint description*	*Mandatory / guidance*	*High / medium / low*	*[initials]*	*[Organisation name]*	*[Person name]*
FT10.1	0	0	0	0	#N/A	#N/A
SR9.1	0	0	0	0	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

The same combination of input window, remarks table and applying requirements table is provided for the line diagram and a layout drawing (e.g. the 2D or 3D simulation model window from the Enterprise Dynamics application).

The concerning engineer enters the requirement or constraint ID code in the white left column. Then automatically the other related information is displayed, obtained from the Stakeholder and Requirements worksheet.

Some default ID codes are given in the tables. They refer to relation between the concept and the requirements that exist for certain.

2 Technology specification

2.1 Check-in technology

Author	Technology	Comments
[initials]	*[specification of the applied check-in technology]*	*[Comments regarding the check-in technology]*
BB	50 walk-through check-in desks, combined with 25 elevators (type X1200 from subcontractor TD)	Stainless steel covers. Weighing belts included.

[Requirements and/or constraints concerning the check-in technology]

Requirem. / constr.	Description	Compliance level	VI Priority	Assigned to	Organsiation	Person
[ID code]	*[Requirement / constraint description*	*Mandatory / guidance*	*High / medium / low*	*[initials]*	*[Organisation name]*	*[Person name]*
FT1.1	Walk-through check-in desks	Mandatory	High	MF	FlyHappy Airport	Mike Flight
FT1.2	0	0	0	0	#N/A	#N/A
FT1.3	0	0	0	0	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

This combination of description table and relevant requirements table is repeated for the following technology: transport, sorting, make-up, break, HBS, EBS, controls, consolidation and other.

3 Cost effectiveness

[To what extent fulfils the system its function in a desired way against the lowest possible life cycle cost]

3.1 Throughput

[Possible descriptions:
Flow throughput divided per source such as check-in, transfer, other terminal and terminating
Flow throughput per system component
Description in words, graphs, flow layouts, etc.]

Author	Description	Comments
[initials]	*[specification of the throughput capacities]*	*[Comments regarding the throughput description]*

[Requirements and/or constraints concerning the throughput capacities]

Requirem. / constr.	Description	Compliance level	VI Priority	Assigned to	Organsiation	Person
[ID code]	*[Requirement / constraint description*	*Mandatory / guidance*	*High / medium / low*	*[initials]*	*[Organisation name]*	*[Person name]*
SR1.1	0	0	0	0	#N/A	#N/A
SR1.2	0	0	0	0	#N/A	#N/A
SR1.3	0	0	0	0	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

This combination of description table and relevant requirements table is repeated for all cost effectiveness elements. Below only the hint text for each element is shown.

3.2 In-system-times

[Possible descriptions:
Average, maximum, minimum times, divided by flows
Description in words, graphs, histogram, etc.]

3.3 Resource utilisation

[Possible descriptions:
Percentages busy, stand-by, off per component (-group)
Content in nr. of bags per interval
Description in words, graphs, histogram, etc.]

3.4 Redundancy
[Possible descriptions:
Description in words how to deal with scenario
Results in performance per scenario
Description in words, graphs, histogram, etc.]

3.5 Maintainability
[Possible descriptions:
Maximum time to repair, mean time to repair
Spare parts usage
Maintenance control system
Training requirements
Back-up system (International, remote)
Description in words, graphs, histogram, breakdown structure, etc.]

3.6 Reliability
[Possible descriptions:
Mean time between failure
Maximum time between failure
Description in words, graphs, breakdown structure, etc.]

3.7 Availability
[Possible descriptions:
Percentage of time the system will perform its function
Description in words, graphs, breakdown structure, etc.]

3.8 Flexibility
[Possible descriptions:
Modular BHS composition possibilities
Extendability (future flexibility)
Phaseability
Down-gradeability
Description in words, layouts, etc.]

3.9 Controllability
[Possible descriptions:
Tracking and tracing
Management information
System status information
Interface with existing/other software
Failure modes
Routing and balancing
Peak-shaving
Description in words, layouts, etc.]

3.10 Safety
[Possible descriptions:
Emergency stops
Danger detection
Fencing
Fire protection (not only in a technical way, but also in a “human” way e.g. fire escape routes operators)
Risk Analysis results
Description in words, layouts, etc.]

3.11 Ergonomics
[Possible descriptions:
Noise level
Physical load
Description in words, graphs, etc.]

3.12 Life cycle cost
[Possible descriptions:
Capital expenditures (equipment and controls)
Organisations and Management set up expenditures (training, documentation, Set up tools, initials spares)
Operational expenditures (management, operating and handling team, energy)
Maintenance expenditures (maintenance team and spare parts usage)
Description in words, LCC calculator graphs, tables, breakdown structure, etc.]

4 References

[references to CAD drawings, simulation models, price calculations, text documents, call for tenders, tender documents, etc.]

Document name	**Description**	**Where to find?**
[file name]	*[description of content]*	*[server/department/Internet link]*

Concept history worksheet

BHS concept history

Document objective:
Support the documentation of the evaluation of designed BHS concepts.

Concept 1

Author	Date	Status	Comments
[initials]	*[dd/mm/yyyy]*	*[under construction /approved/rejected]*	*[further details]*

This table is repeated for 5 concepts.

Appendix F: Cost Breakdown Structure

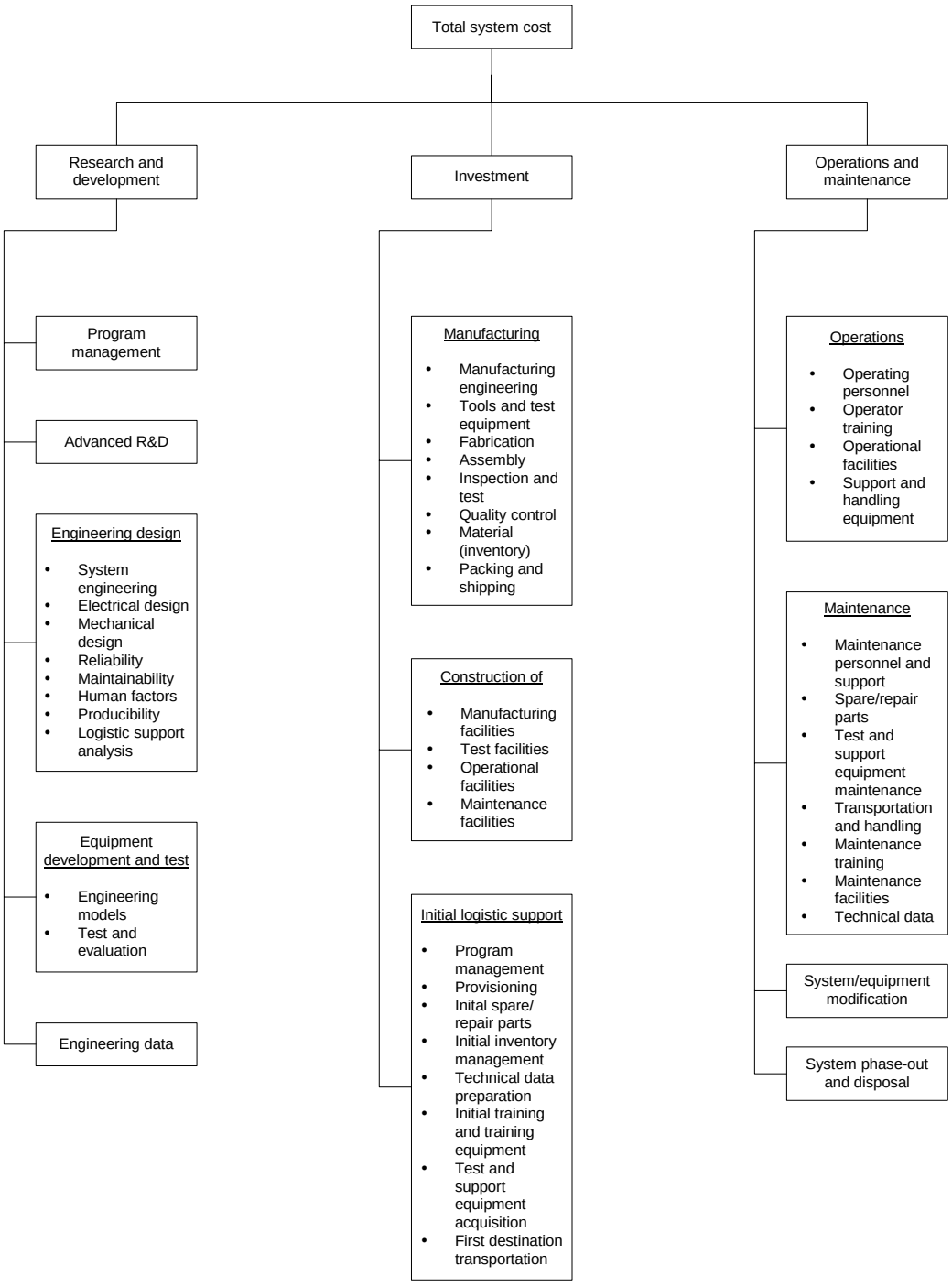


Figure F.1. Cost Breakdown Structure [Blanchard, 1991, p322].

Appendix G: Components of a BHS and their functionality

General name	VI name	Functionality	Object class
Check-in desk / isle	Check-in desk / isle	Weighing Labeling Identification Checking dimensions Dispatch Tipping Transport	Input
Transfer	Transfer loading	Identification Weighing Checking dimensions Transport	
Claim carrousel	Arrival carousel	Loading Transport	
Belt conveyor	Belt conveyor	Transport	Transport
Start/stop belt conveyor	Start/stop belt conveyor	Queuing Transport	
Accumulating conveyor	Accumulating conveyor for tubs	Transport Hold baggage Arrange a uniform flow of baggage	
Belt curve	Belt curve	Transport baggage 2-dimensional	
Tub conveyor	TUBTRAX®	Transport baggage in tub	
DCV	BAGTRAX®	Transport baggage in cart	
Tub loading	Load	Load bag in tub	Process
Tub unloading	Unload	Unload bag from tub	
Cart loading	Load	Load bag in cart	
Cart unloading	Unload	Unload bag from cart	
Carrier load	Charge	Load tub in carrier	
Carrier unload	Discharge	Unload tub from carrier	
Reconciliation	Reconciliation	Match passengers and baggage going into plane	
Handheld scanner	Handheld scanner	Identify bag	
Automated scanner	Automated scanner		
Screening level 1	Screening level 1	Check bags for explosives or drugs	
Screening level 2	Screening level 2		
Screening level 3	Screening level 3		
Baggage storage	EBS: lanes	Temporarily store and release bags	
Baggage storage	EBS: rack		
Baggage storage	EBS: dynamic		

p.t.o.

continuation…

General name	VI name	Functionality	Object class
Pusher	Diverter Parallel Pusher	Divide one baggage flow into two baggage flows	Sort
Plough	Vertibelt		
Cross belt	Cross belt		
Vertical sortation unit	VERTISORTER®		
Tray sorter	Tilt-tray sorter	Divide one or more baggage flows into two or more baggage flows	
	HELIXORTER®		
Carrousel	TRIPLANAR® sorter		
Shoe sorter	POSISORTER®		
Side merge	Beltjunction 45°	Consolidate two baggage flows into one baggage flow	Merge
Vertical merge	Vertimerge		
End merge	End merge		
Induction	Induct		
Chute	Chute	Guide baggage (by gravity)	Output
Bin	Bin	Collect baggage	
Spur	Spur	Collect baggage Arrange baggage flow by gravity	
Lateral	Lateral	Collect baggage Arrange baggage flow	
Control system	Controls	Control the total BHS	Controls
Maintenance man	First line maintenance man	Perform basic / visual maintenance activities	Employee
Maintenance man specialised	Second line maintenance man	Perform specialised maintenance activities	
Baggage handler	Baggage handler	Handle bags	
Operations manager	Operation manager	Manage the BHS operations	
Operations man	Control room employee	Control the BHS	

Table G.1. The components of a BHS and their functionality.

Appendix H: Object model of a BHS

Object class Input
[attribute
Name (check-in isle, belt conveyor loading, TRIPLANAR® flat make-up) [string]
Number of desks [integer]
Maximum peak capacity (bags/hour) [integer]
Handling time (sec) [time]

actions
Introduce bag into system
]

Object class Transport
[attribute
Name (Belt conveyor, start/stop belt conveyor, accumulating conveyor, belt curve, TUBTRAX®, BAGTRAX®) [string]
Length (m) [real]
Angle (º) [real]
Speed (m/min) [real]
Maximum peak capacity (bags/hour) [integer]

actions
Transport bag between two points
]

Object class Process
[attribute
Name (EBS lanes, EBS rack, EBS dynamic, screen level 1, screen level 2, screen level 3, manual scan, automated scan, load, unload, charge, discharge, reconciliation) [string]
Maximum peak capacity (bags/hour) [integer]
Maximum store capacity (number of bags) [integer]
Process time (sec) [time]

actions
Process bag
]

Object class Output
[attribute
Name (bin, lateral, TRIPLANAR®) [string]
Status (open, closed) [string]
Length (m) [real]
Capacity (number of bags) [integer]
Handling time (sec) [time]

actions
Bring bag out of the system
]

Object class Sort
[attribute
Name (pusher, vertibelt, cross belt, VERTISORTER® , tilt-tray sorter, HELIXORTER® , TRIPLANAR® sorter, POSISORTER® [string]
Number of inlets [integer]
Number of outlets [integer]
Number of positions [integer]
Length (m) [real]
Speed (m/s) [real]
Maximum peak capacity (bags/hour) [integer]
Handling time (sec) [time]
Capacity (number of bags) [integer]

actions
Sort bag in different directions
]

Object class Merge
[attribute
Name (side merge, vertimerge, end merge) [string]
Length (m) [real]
Speed (m/s) [real]
Maximum peak capacity (bags/hour) [integer]
Handling time (sec) [time]

actions
Merge bag from different directions
]

Object class Bag
[attribute
Bag number [integer]
Time in [time]
Time out [time]
Standard Time of Departure [time]
Flight code [string]
Out of gauge (yes, no) [boolean]
Status screening (not screened, level 1 screened, level 2 screened, level 3 screened) [string]
Status EBS (yes, no) [boolean]
Baggage category (originating, transfer, destinating) [string]

actions
]

Object class Controls
[attribute
Price [real]

actions
Control the BHS
]

Object class Employee
[attribute
Function [integer]
Labour cost per hour [real]

actions

Appendix I: Enterprise Dynamics and the BAX Suite evaluation

Supplier: Incontrol Simulation Software b.v., Maarsen
Based on ED Version 3.4 and BAX Suite Version 01-b

I.1 Introduction

This appendix evaluates the usefulness of the software for building simulation models of Baggage Handling Systems in order to obtain information about the dynamic behaviour of the system. It is based on a stand-alone installation with a hardware key with code ZWBXO.

Enterprise Dynamics and Airport Suite are trademarks of Incontrol Simulation Software b.v. in Maarssen, The Netherlands. The Enterprise Dynamics Airport Suite is a library of simulation objects made for the airport industry. One of the modules is ED BAXSIM. That's a library with building blocks (atoms) for simulation models of Baggage Handling Systems on airports, which can be loaded into the main ED library. In order to determine the usefulness of both the ED package and the BAXSIM module, three simulation models of Baggage Handling Systems were built, at two different levels of detail.

The ED software evaluation, which in most cases also implies the BAXSIM atoms, is based on the criteria in the simulation software tool selection of Nikoukaran (Wintersim, 1999):

Criteria	Explanation
Vendor	Criteria related to the evaluation of the credibility of the vendor and to some extend his/her software
Model and input	Issues related to a model, its developments and data input
Execution	Issues related to experimentation
Animation	Issues related to creation, running and quality of animation
Testing and efficiency	Issues for evaluation of testability, debugging power and efficiency of a package
Output	Kinds of output and included analysis instruments
User	Needs and circumstances to be able to use the simulation language

These criteria are divided in several sections. In each section the possibilities of the ED package are subscribed and remarks are added for improvements when the possibilities of the software do not meet the wished requirements of the user. *Also included are the reactions of Incontrol Enterprise Dynamics (further referred to as Incontrol ED) on the remarks. These reactions are added to the remarks and are written in italic.*

Chapter I.2 describes the concept ED is based on, the atom. Chapter I.3 up to I.9 deal with the criteria as introduced above. The final chapter I.10 deals with the suggestions for improvement of the atoms of the BAX Suite specifically.

I.2 Enterprise Dynamics; the atom concept

The atom is the most important thing in Enterprise Dynamics (ED). The atom's main characteristics are:

- It has 4 dimensions (location and speed in space (x,y,z) and dynamic behaviour in time)
- Everything is an atom (the model, the BAX Suite, etc.)
- Every atom can contain other atoms
- It can inherit from other atoms
- It can be created and destroyed
- It can be moved from one atom into another

The atoms are hierarchically structured. At the top of the tree is the main atom. Normally the main atom will contain at least three atoms: the application atom, the library atom and the model atom. The library atom generally contains a number of atoms with predefined functionalities to be used when building a model.

All atoms have the same structure, with the following characteristics:

- Description and identification (Name, ID, Color, Icon, Info, Mother)
- Display settings (defining the animation of the atom)
- Channels (number of input and output channels)
- Behaviour (defined behaviour at the event handlers)
- Attributes
- Table (each atom has its own data table)
- Spatial (location, size and speed)
- Label fields

By using the atom editor, these characteristics can be accessed and changed. When an atom is created it is always a daughter of another atom. This other atom can be an existing atom from a library, but can also be a base class atom. A base class atom is an "empty" atom that has no functionality and only has default settings like: no attributes, no behaviour, an empty table and its colour is black. All atoms are built using the ED programming language called 4Dscript.

I.3 Vendor

I.3.1 Pedigree

Pedigree discusses issues on the historical information about the software and the vendor. It includes age of the software, references, upgrades, other products and spread of the product.

Characteristics	Remarks
Enterprise Dynamics focuses on large and medium sized companies and authorities. Main markets are industry (manufacturing, material handling, warehousing) and infrastructure (airports, ports, rail).	
References: several case studies are placed on their website (www.EnterpriseDynamics.com)	
ED can be used for capacity determinations, designing internal transport systems, designing warehouse (size, strategy and transport), storage levels analysis, bottleneck analysis and performance analysis. Cost / benefit analysis is not supported by ED.	*Incontrol ED: The cost / benefit analysis can be done using cost atoms, attributes, event handlers and 4DScript.*
Updates of the software are supplied on the Internet. Planned new versions of ED every year in October, updates after 3 and 7 months.	
Object oriented character: The atoms have hierarchical features (inheritance of behaviour) and are partly acting as individual objects. In order to achieve total encapsulation additional 4Dscript is required (to protect some typical attributes and behaviour of atoms against interference of other atoms, e.g. a screening machine can change the dimensions of a bag, etc.).	

I.3.2 Documentation

Documentation discusses issues on availability of a manual, tutorials, examples and troubleshooting guide that make learning a new piece of software enjoyable.

Possibilities	Remarks
User Manual: Engine; describes the functionality of the simulation engine. User Manual: Tutorial; general introduction in building models (including a developer part to develop new atoms). User Manual: 4Dscript Manual; gives an overview of all words of the programming language 4Dscript and the syntax rules and common errors. User Manual: Atom Manual; Describes the functionality of the atoms that are part of the ED atom library. It also includes sample models.	
Tutorial software integrated and several useful sample models added.	

I.3.3 Support

Support means the availability of experts that can help, training, maintenance, consultancy, updates, newsletter, user group meetings and Internet discussions.

Possibilities	Remarks
Quick respond on questions asked by e-mail.	
Internet possibilities: Update downloads	*Incontrol ED: Meetings can be scheduled.*

Possibilities	Remarks
Technical support (FAQ) Tips & Tricks for registered users (under construction Nov2001) WebEX: online meetings for registered users (facility implemented on website but no meetings planned yet Nov2001)	*Incontrol ED: MyPlant has a section for ED.*
Incontrol ED has experience with projects at Schiphol Airport, so knowledge of BHS is available.	*Incontrol ED: Incontrol Enterprise Dynamics has a large experience in the simulation of Baggage handling systems at Schiphol Airport, so knowledge of BHS is available to a high level.*
Incontrol ED additional services: consultancy and training (basic and advanced). Incontrol ED develops an Education Suite (easy to use modelling objects for queuing cases)	
(Potential) user group meetings organised (e.g. The European Simulation Conference).	

I.3.4 Pre-purchase

Pre-purchase facilities include demo disks, free trials and on-site demonstrations.

Possibilities	Remarks
Evaluation version of ED can be downloaded (up to 20 atoms can be saved, no connections with external programs possible) from the Internet.	*Incontrol ED: Connections with external software possible in evaluation version of ED 4.0.*
Trial period of simulation software is possible by means of software rental.	
Incontrol ED organises hotel seminars for interested people.	

I.4 Model and input

I.4.1 Model building

This section discusses issues related to creating and manipulating models. Some of the issues considered are graphical model development, coding, creation of reusable components (libraries), errors and suggestions during creation.

Possibilities	Remarks
No undo / redo function.	Wish: an undo / redo function is a must for building models without frustration.
Not possible to open two or more models separately at the same time in order to compare or copy several model parts directly.	Wish: possibility to open more than one model at the same time.

Possibilities	Remarks
	Incontrol ED: It is possible to open a second model in an open model (in a container or by merging two models).
The atoms automatically connect when created.	The auto-connect-function, built in standard behaviour of all atoms, is in most cases unwanted (sequence of building a model almost never equals the sequence of the routing). *Incontrol ED: It can easily be switched off.*
Reading the names of the attributes of the atoms in the atom editor table is limited to 10 characters.	Wish: an adjustable column width in the attribute table to the wideness of the name of the attribute. *Incontrol ED: Is already implemented in ED 4.*
Building a model means dragging and dropping atoms from the library into the model layout. Because of the use of atoms (“building objects”), the modelling speed can be high. Based on the “enter once, use often” concept atoms (and thus models) can be reused. Building a model is a combination of behaviour programming and menu options. In these menus 4Dscript programming options are possible in the standard “on entry” and “on exit” menu fields. It is possible to edit or create atoms by using the atom editor: When double clicking on event handlers the software asks if you want to get the inherit code. Answering yes overwrites the code given in by hand. The code typed in an event handler field is also deleted if the tree is refreshed before the atom in the library is clicked. When the behaviour of an atom is changed, it has to be saved before closing ED, otherwise the changes are not saved. When a model is opened and saved without the necessary	

Possibilities	Remarks
atoms loaded in the library, the concerning atoms lose all their behaviour and attributes. If, after that, the model is opened with the necessary atoms in the library, the concerning atoms are still completely empty.	
Hierarchical tree structure of the model (and library). Additional atoms can be loaded into the library one for one.	Wish: possible to select more atoms at once in order to load them into the library. *Incontrol ED: Multiple atoms can be joined in one atom and then saved and loaded. E.g. all the ED BAXSIM atoms can be loaded together.*
Selection of more than one atom in the model layout view is only possible by using the "Atom Manipulator" atom.	Wish: possibility to select (e.g. by mouse in combination with Ctrl-key) more than one atom (e.g. in order to move them)
Graphical oriented. The routing through the model is given by connecting the atoms with channels, which increases the building speed of small models. When the model gets more complex, zooming in is required in order to distinguish the different channels. This is a limitation, especially when the atoms that have to be connected are distant. Keeping the overview of the model's atoms with the "view channels" option on is hard. By using the "Atom Manipulator" atom, parts of the model can be selected in order to hide the involved channels. But this activity takes much time.	Wish: possibility to change the way the channels are lay down in the model layout (make it flexible connectors in order to create a conveniently arranged overview) Wish: possibility to develop models in different layers. *Incontrol ED: Containers can be very useful to create sub models (layers).* *Incontrol ED: Atoms can also be connected by selecting the atom and channel to connect to from a list.*
By default the dimensions of the atoms as displayed are used in the logic. This connection can be switched of in the pop up menu of every atom ("Use physical dimension").	

I.4.2 Input of data

Provide the simulation model with data. Important issues include reading from file, variables that need to be set, interactive input with menus, automatically read from database, checking input values.

Possibilities	Remarks
After (and during) building a model, the reset function makes it possible to check the consistence of the model before running it.	

When wrong syntax is entered in an atom this is reported in the error monitor right after the “apply” or “ok” button of the 4Dscript window is activated (or on clicking the F10 button). Some input parameters of the atoms are checked automatically. If the entered value or string is not correct, the possible range is displayed. By pressing the F11 button on the keyboard, the syntax in the 4Dscript window is colored by group. This way of displaying makes it easier to check the syntax on consistency. In the 2D visualisation window the channels can be shown in order to check the connections.	There are also atoms / parameters without an input check (e.g. in the “send to” statements percentages of 150% and –10% are accepted).
When a lot of the same atoms are used in the model and a parameter of all these atoms must be changed, it can not be done centrally. Contrary to the parameters, the behaviour of the atoms can be changed in the “mother” atom in order to change it in al the atoms in the model.	*Incontrol ED: This can be done using 4Dscript.*
Ways of communicating with external applications: DDE (Dynamic Data Exchange) DLL (Dynamic Link Library) Window sockets ODBC driver (database). Real-time control: Socket interface, ODBC driver and DLL supported. Distributed simulation: No features like sharing an event list supported.	*Incontrol ED: ED does support* *TCP/IP communication.*
The parameters can be changed during a simulation run by entering the pop-up menus. If the atoms need a reset (in order to calculate something based on the involved parameter) the results of the change aren’t implemented immediately.	

I.4.3 Statistical distributions

Features discussed include approximating observations values to distributions functions, available number of distributions, seed values for conditions and random generators.

Possibilities	Remarks
ED includes an input analyser that can read from a ED table or an Excel sheet. It calculates the best distribution fit, including the parameters.	
All common distributions are available in ED by 4Dscript. The seed value for the 100 random generators can be set in the main menu.	

I.4.4 Coding aspects

Possibility to enlarge the flexibility by adding user code to the simulation model.

Possibilities	Remarks
The 4Dscript overview can be chosen from the main menu in order to support writing 4Dscript code.	
Every behaviour, decision rule, etc. can be modified by extending the existing 4Dscript or define new routines. When default 4DScript is changed (e.g. set the "send to" percentage 75% to channel 4), the default value must be selected first in order to be able to remove or change it. Every atom owns event handlers like "on entry" and "on reset" that can be modified in the parameter menu.	Wish: same edit possibilities of text in the 4Dscript window as Microsoft Word (not required to select first)

I.4.5 Queueing policies

Available queueing methods like FIFO, LIFO, minimum value and maximum value.

Possibilities	Remarks
Besides some included sorting controls (such as FIFO, LIFO, sorting by label and random) the sorting control can also be defined in 4Dscript.	

I.4.6 Other items

Possibilities	Remarks
The availability of all atoms can be influenced by the "Availability Control" atom in combination with the "Mtbf Mttr Availability" atom. These atoms include deterministic as well as stochastic down periods and intervals. It is also possible to turn the availability of one or more atoms of by clicking the "Switch Availability" atom by mouse. The time "Schedule Availability" atom allows the user to create a down period table.	

I.5 Execution

I.5.1 Multiple runs

Possibility to execute a simulation replication several times without user interface.

Possibilities	Remarks
When the atom "Experiment" is placed in the model-atom, it is possible to define the number of runs (observations) including the run length and warm-up period.	
Possibility to set "repetitive" on, in order to get the exact same stream of random numbers after reset and run again.	
The run length can be defined in various units of time or in 4Dscript.	

I.5.2 Automatic batchrun

Feature to execute several simulation runs with different sets of parameters, for several replications without user interface.

Possibilities	Remarks
Not possible.	*Incontrol ED: There is an atom available that supports this functionality.See Myplant.*

I.5.3 Warm-up period

Feature to start gather data after the simulation has been started.

Possibilities	Remarks
Yes, defined by a unit of time or by entering 4Dscript.	

I.5.4 Reset capabilities

Possibility to stop the simulation during a run and restart.

Possibilities	Remarks
Yes, the Run Control Window contains start, stop, pause, reset and step facilities.	

I.5.5 Start in not empty state

Possibility to start with a simulation model in which already objects or entities are included.

Possibilities	Remarks
Entering 4Dscript in the “OnCreation” event handler makes it possible.	

I.5.6 Speed control

Possibility to change the speed of the simulation, link to a real time clock, stop and start, save model during the run.

Possibilities	Remarks
The Run Control Window contains the follow options: Reset, run, stop, step Speed options (unlimited, real time (approximately), slide control, custom (sec, min or hours /real sec), synchro real time (catch up and slow down)) Slide control (slide control to change the speed continuously between pause and unlimited.	

I.5.7 Executable models

Availability of pack and go versions that can be shown at any location at any PC, just with a part of the simulation, or no simulation software at all.

Possibilities	Remarks
Not available.	

I.6 Animation

I.6.1 Integrity

Animation comes as an integral part of the package or is added.

Possibilities	Remarks
Integral animation. ED is appropriate for building models at a high and middle level of abstraction. When a very detailed model is required, the possibilities of using 4Dscript are infinite, but that takes a lot of time.	

I.6.2 Icons

Libraries with standard icons to be used, possibility to read CAD drawings, bitmaps and OLE-objects.

Possibilities	Remarks
Enterprise Dynamics supports *.jpg, *.wmf and *.bmp formats for 2D images. These images can be used as background or visualise any object in the simulation model. Imported icons for atoms do not scale when zooming in or out.	Future wish: not only visual link but also a functionality link between e.g. AutoCad and ED objects. Wish: use same scale rate for icons as atom it self.
VRML objects can be imported and connected to atoms for a VR representation.	
Other objects can also be imported and activated in run time (e.g. Powerpoint slide shows, sounds).	

I.6.3 Screen layout

Includes issues such as graphical representation of the model on the screen and showing multiple views of the model.

Possibilities	Remarks
Creating a model in the 2D model layout window results in a schematic animation of the model. When running the model, the atoms and atom flows are animated in a simplified way (e.g. the content of a queue is displayed as a bar graph if capacity < 10). In the 3D window and virtual reality window a more realistic reproduction is automatically generated.	

When a model is created in the 2D model layout window, a 3D visualisation is created automatically.	The shadow of a rotated “Non accumulating conveyor” atom is animated in a wrong way.
Not possible to define some “named views”, in order to go through the model by using only the defined keys on the keyboard.	Wish: option of “named views” (you link a certain view to a unique key which you can use during building, validating and presenting the model)
When atoms (and/or there icons) overlap, there is no possibility to send them to back or front.	Wish: possibility to send atoms to front or back.
No standard drawing objects are implemented in ED (e.g. line and shape atoms)	Wish: In order to maintain overview on a big model, some standard drawing possibilities are required.
The visualisations of atoms, including their contents, disappear when the “core” (the actual atom) is of the screen. This way zooming in order to observe parts of a model gets hard.	Wish: enlarge range in which the atoms are visualised (also visualise if atom is of the screen).
In big models the visualisation of the channels is chaotic.	Wish: The channels should be more flexible. If the user can drag the channels in a certain shape, the overview with the option “show channels” is much better.

I.6.4 Features

3D, color, resizing, zooming and pixel-vector.

Possibilities	Remarks
Choosing the virtual reality option from the main menu allows the user to “fly” through the 3D model. It is also possible to follow a certain atom through the 3D model by using the “Camera” atom and to change the shadows of the atoms by using the “Light” atom.	
Scrolling through the models by dragging with the mouse. If both mouse buttons are used in the same time, it is possible to zoom in and out.	If unintentionally an atom is selected, which happens very often when zoomed in by clicking even near the atom, it is moved through the model, instead of moving through the model it self.

I.6.5 Animation development

Includes issues such as ability to create and import icons, quality of icons and collection of animation icons.

Possibilities	Remarks
ED contains some simple icons that will do in models with high and medium level of detail. See section I.6.2: importing icons	

I.6.6 Running

Animation events during the run, show or hide changes of animation.

Possibilities	Remarks
The slide control function allows the user to adjust the simulation speed to the ideal observation speed. By changing the colour of atoms after a certain assignment (by adding 4dScript) it is easy to follow individual atoms in their way through the model.	
During the run the 2D and 3D windows can be opened and closed. Opening these windows results in a drastic decrease of the run speed.	
Every table that is created (at reset or during the run) can be displayed during the run. The (simplified) graphs in the “Monitor” atom are refreshed during the run with a user-defined interval. The graphs created by the “Graph” atom are only refreshed after double clicking the atom in the 2D window.	
Included in ED are several colour changes when the status of an atom is changed (e.g. when a conveyor is not available, the colour of the conveyor turns red). By using the “Monitor” atom, the status of each atom can be animated in text or value.	
Queues with a maximum capacity up to 10 display (animate) the atoms they contain, bigger queues display a red bar to indicate the level of occupancy. The number of atoms in the queue is always displayed in the 2D window.	

I.7 Testing and efficiency

I.7.1 Verification and validation

Includes on-line help, on-line error messages, on-line tutorial, logical error checks, syntax error checks and clear error handling.

Possibilities	Remarks
If an error occurs while running or resetting a model, the error monitor pops up (if it was already popped up, the background colour of the monitor is changed). The monitor will list the ID of the involved atom, the event the error occurred on and gives a short description. The exact error is not mentioned. The error monitor is not emptied after a message. All new and old messages are displayed without a distinction.	- Wish: (if possible) more accurate error messages (not “the statement is not correct” but “a bracket missing at the end of that statement”). - Wish: distinction in the error messages between “old” and “new” messages.

I.7.2 Multitasking

Possibility to execute several tasks at the same time (as user) for example build a model and run replications with an other.

Possibilities	Remarks
Not possible in ED.	- Wish: possibility to open more then one model in order to compare model structures, etc. *Incontrol ED: However, it is possible to change a model during run time, without compiling.*

I.7.3 Interaction

Interaction of the simulation model, change of the model and continuing the executing of the model.

Possibilities	Remarks
By using the Interact Window, any 4Dscript statement can be executed during or after a run by clicking on "execute".	
The tracer window can be used, to write messages to (in 4Dscript) without stopping the simulation run.	
All parameters can be changed during the run, but some of them are only executed on reset (e.g. if the discharge frequency of a tray sorter is changed (the number of trays), the logic needs the speed of the sorter and the size of the trays too).	
Easy entering of the atom's behaviour via the atom-editor. Changing the behaviour of the mother results in changes in the behaviour of all the daughters too. Changing parameters of atoms means opening them one-for-one. The hierarchy doesn't apply on the parameters.	
Reading the labels of atoms by using the "tools" menu and the option "view atom labels" or by a right mouse click in the modeltree. If more atoms are in another atom, they can not be distinguished. Reading the attributes by using the atom editor (no distinction possible between the baggage atoms e.g.)	- Wish: possibility to double click on a (baggage or product) atom in the 2D-view in order to see the labels and attributes. *Incontrol ED: It is now possible to double click on a baggage atom in order to see the attributes.*
The simulation can be stopped and continued during the run (see explanation of Run Control Window in section I.5.6, Speed Control).	

I.7.4 Step function

Running the model event by event, lets the user observe the changes in each state.

Possibilities	Remarks
Step function is integrated in the Run Control Window (see section I.5.6, Speed Control).	

I.7.5 Backwards clock

Running the model backward would help debug the errors which occurred during the model normal run and which the program did not detect or could not stop at the time.

Possibilities	Remarks
Not possible in ED.	

I.7.6 Breakpoints

Possibility to stop the model at any given moment, piece of code or condition.

Possibilities	Remarks
By adding 4Dscript the simulation can be stopped at a certain time (not included as a separate function).	

I.7.7 Display features

Dynamic display of variables, attributes and functions, during the run and during debugging.

Possibilities	Remarks
The “monitor” atom can be linked to any atom in the model and is able to display properties like average content, current content, average stay time, status and output. The user can also define other properties in 4Dscript. Some atoms display in the 2D window their main performance indicator (e.g. the output of a source, the occupancy of a server and the content of a queue).	- Wish: A stand-alone variable atom that can be placed in the model atom and displays its current value (with options in displaying the value over time, etc.). *Incontrol ED: In E.D. 4.0 a ‘watches’ window is available that shows values of expressions in run time.*
The “clock” item, which can be chosen from the main pull down menu, has different ways of displaying the time (analogue, digital) and the date. The refresh period can be adjusted (high, normal and low frequency).	

I.8 Output

I.8.1 Reports

Standard reports about queue lengths, waiting times, etc.

Possibilities	Remarks
The standard report includes the current and average content, the throughput and the average stay time of all atoms. Besides that the start and stop time are reported, together with the run length in seconds.	
The average occupancies of servers are displayed in the 2D window.	
The atom status percentages can be reported after the run length has passed.	
The structure of the model atom is always given in the model window. The model documentation can also be written into a separate file (.txt) by using the "Model documentation" atom. The following properties can be included (defined by user): atom name, mother name, container name, attributes, channels, location, size and labels.	

I.8.2 Delivery

Creating your own reports with extra information, or direct send the output to a printer.

Possibilities	Remarks
By using the "Summary report" atom, personal reports can be defined. After choosing the atoms to include in the report the following properties can be included: current content, average content, maximum content, average stay time, input/output quantity, current atom status and the atom status percentages. Besides these properties the analysis start and duration time can be assigned.	
In order to write leadtimes to a table, the entry time must be defined in each starting location (if the starting location is a "source", the leadtimes can be defined by the age of a atom, which is included in the standard "Data recorder" atom).	

I.8.3 Integration

Links to other packages to handle the data, for example links to planning tools or optimisation programs.

Possibilities	Remarks
Optimisation not standard included.	*Incontrol ED: ED provides an Optquest link. Optquest has to be purchased separately.*

I.8.4 Database

Possibility to store and evaluate the data in a database.

Possibilities	Remarks
The tables, created automatically or defined with the "Data recorder" atom, can be copied in e.g. Excel by the Windows copy & paste functions. The "Export table" atom only writes tables in text (.txt) files. The "Data recorder" atom makes it possible to write data into Excel or Word files during the run.	*Incontrol ED: Database link via ODBC. Writing data to a database is very fast. The Database atom can be used to connect to a database, view the database and perform queries on it.*

I.8.5 Business graphics

Graphs, plotters, histograms, etc, during the run and after the run.

Possibilities	Remarks
The "monitor" atom also includes an elementary graph that is updated during the run. After the run several graphs can be produced with the option "graphs" in the results menu. By using the graph option, a histogram (and other graph types) can be made of several performance indicators such as the waiting times in a queue or on a conveyor.	

I.8.6 Statistical

Calculations such as means, variances, half width, t-test, etc.

Possibilities	Remarks
Only means of staying times integrated in reports.	

I.9 User

I.9.1 Hardware

Desired hardware to run the simulation package.

Possibilities	Remarks
Workstation including mouse, monitor (resolution 1024x786 minimum) and keyboard. Pentium II processor, minimum necessary memory hard disc: 50Mb and 32Mb RAM.	

I.9.2 Operating system

Desired operation system to run the simulation language.

Possibilities	Remarks
Windows 95 / NT.	*Incontrol ED: ED Version 4.0 requires Windows 98, ME or 2000.*

I.9.3 Network version

Possibility to use network licences.

Possibilities	Remarks
Yes.	

I.9.4 Required experience

Assumed preliminary knowledge, before starting to use the package.

Possibilities	Remarks
User interface is written in English. Because of the graphical model building, ED is mastered by beginning engineers easily.	

I.9.5 Financial

Costs of the package, hardware and learn time.

Possibilities	Remarks
ED, 3 year contract periods: 1 technology license: 7.500 Euro per year 1 user license: 2.500 Euro per year Includes maintenance and helpdesk.	

I.9.6 Security device

Hardware dongle, software number.

Possibilities	Remarks
Evaluation Version for free (up to 20 atoms can be saved, no connections with external programs). The normal versions are protected by hardware keys and licence numbers.	

I.10 BAX Suite atoms

For ED BAXSIM a tutorial, atom reference and sample models are available. Case studies and further information can be found on www.EnterpriseDynamics.com and www.AirportSuite.com.

The atoms mentioned in the first column are atoms of the ED BAXSIM module of the ED Airport Suite. The referred atoms in the second column exist in the Logistics Suite of ED.

Atom	Characteristics	Remarks
The BAX Atom	Contains the atoms for modelling BHS. Version 01-b.	
A001-AtomAttributes	Not intended to drag into a model	

Atom	Characteristics	Remarks
A002- Baggage	Similar to “product” atom, extended with extra attributes	- Double click on the “Baggage” atom results in error message (see [1)]) *Incontrol ED: bug already fixed.*
A003- Baggage Generator	Similar to “source” atom, extended with bag dimensions and color, percentage OOG, internal arrival table of baggage (nr. of bags with attributes per time interval), excel/database data link	
A003- Baggage Generator FS	Similar to “Baggage Generator”, but instead of arrival table of baggage an arrival patterns table of passengers (nr. of passengers per time interval relative to STD) and a flight schedule table	*Incontrol ED: Baggage can be generated according to a flight schedule (FS) and passenger arrival patterns.* *Incontrol ED: Provides a link with Excel or a database to read data from (either baggage data or flight schedule data). See also example model.*
A005- Baggage Source	Similar to “source” atom	
A006- Carousel	Composition of “conveyors”, “curved conveyors”, “server” (without the occupancy) and “sink” atoms	- Added value: in case several carousels with different dimensions have to be modelled. - Wish: display the occupancy of the carousel server in 2D windows. - Shadow in 3D view is incorrect when carousel is rotated.
A007- Check-inBlock	Similar to “queue” and “server” atom, extended with attribute “average waiting time” and histogram of waiting time	- Added value: histogram of waiting times - Wish: show the occupancy of the check-in server in 2D windows.
A008- Curved Non Accumulating Conveyor	Not available in the standard Logistics Suite	
A009- Manual Encoding Station	Similar to composition of “non-accumulating conveyor” and “server” atom, extended with 2 process times with chance and interval table with number of bags and occupancy	- Added value: no 4dScript necessary to define two process times and per interval number of bags and the occupancy rate (instead of average, over-all occupancy rate of normal “server” atom)

Atom	Characteristics	Remarks
A010- Fast Non Accumulating Conveyor	Similar to “non-accumulating conveyor”, without the number of animated supports, but extended with some attributes necessary for the “merge” atom	- Shadow in 3D view is incorrect when conveyor is rotated - Capacity is calculated wrongly when not using the “physical length” option *Incontrol ED: the calculation problem is worked on*
A011- Switch	Similar to “node” atom, extended with “only rotate when empty” option and better 2D/3D animation	
A012- Lateral Sink	Similar to composition of “server” and “sink” atom	
A013- Line Sorter	“Non-accumulating conveyor” atom, extended with several outlets	- Added value: many discharge conditions by menu, rest by 4Dscript *Incontrol ED: Added value: one conveyor with many exit points (less conveyors needed in the model).*
A014- Merge	Uses attributes of the conveyors of the BAX Suite	- Wish: Merge atom possible at different transport heights via menu (now only via atom editor)
A015- Originating Point	Similar to “check-in block” atom	
A016- Automatic Encoding Station	Similar to “non-accumulating conveyor” atom, extended by “no read percentage” option and a bow in 3D animation	- Added value: animated bow in 3D and no 4Dscript necessary for “no read percentage” option (menu controlled). - No data entry check (no read percentage of 150% and –10% possible).
A017- Screening Machine	Similar to “non-accumulating conveyor” atom, extended with “capacity” option, 4Dscript field for “set screen status” option, “3-phase failure rate” option and a 3D animation. The failure rate of screening machines MUST be given (1-9999999999).	- Wish: several options of distributions in a “set screen status” pull-down window, instead of only a 4Dscript field. - Wish: possibility to set failure rate to 0.

Atom	Characteristics	Remarks
A018- Sorter Curve		
A019- Sorter Discharge		- Wish: distinction between the “sorter induction” atom and the “sorter discharge” atom in the “view channels” screen layout. - Wish: automatically height adjustment to the height of the “tray sorter” atom (4Dscript at reset event handler). - Wish: possibility to set a certain distance between discharge point and decision point of discharge/no discharge (reality: 2 – 3 metres in front of discharge point).
A020- Sorter Induction		- Wish: distinction between the “sorter induction” atom and the “sorter discharge” atom in the “view channels” screen layout. - Wish: automatically height adjustment to the height of the “tray sorter” atom (4Dscript at reset event handler). - Induction frequency can only be given in time between two inductions. Wish: option to give the number of trays that must pass before another induction can be accomplished.
A021- Sorter Scan		
A022- High Aggregation Storage	Storage with the following options: store capacity, store time (4Dscript), inbound capacity and outbound capacity. In 2D animation the contents (number of bags), the current utility and the average utility are shown.	- In 3D animation no bags are shown and in 2D only 1 bag is shown. *Incontrol ED: All atoms in the storage are accessible with the atom editor.*
A023- Transfer Unloading Quay	Similar to “Check-in block”	
A024- Tray Sorter	Container for the curves, scan, discharge and induction points. The Structure Table is the most important part of the atom.	- Wish: A pull-down menu in the ”Define Structure” table in order to choose the atoms (present in the container) instead of typing the names (would be faster and prevents mistakes). - Wish: automatically set of the type of the atoms in the structure table e.g. based on the

Atom	Characteristics	Remarks
		"mother type" of the atoms (faster and prevents mistakes)
	When scrolling through model layout, the trays (including contents) of the tray sorter disappear when the atom-block of the sorter is of the screen.	- Wish: Always display the atom contents, also when the atom itself is out of sight. - The physical distances of the tray sorter components (discharge/induction/scanning) are not used to set the structure table, so great differences between "what you see" and "what really happens" can occur. Wish: automatic filling of the structure table based on the physical distances in the model layout view.
	Statistics about the occupancy rate of the inducts and discharges can be shown in a table by clicking on the concerning induct or discharge.	- Wish: statistics about the occupancy rates of the discharge and induction points grouped in one view/table and easily exported into Excel. *Incontrol ED: Export to excel is always possible using Copy&Paste functions.* - A lot of error messages pop up that can be ignored when clicking on reset in order to define the shape of the sorter. *Incontrol ED: The error messages are obviated. Now only some tracer messages appear about not-connected atoms.* - Not clear how priority is set. In default situation most priorities are 1, some 14,674564 etc. *Incontrol ED: Priority set can be given in the sorter atom.*
A025- Tub Station	Composition of "server" and "non-accumulating conveyor" atom, extended with "tub change (%)", "capacity (bag/hr)", "tub length" and "tub width" options by menu. In 2D and 3D animation tubs are added.	
A026- Vertical Sorter	Includes options like "length", "speed", "rotate empty (y/n)", "rotate time".	- Wish: possibility to choose from the menu a sorting condition "in turns" (channel 1, channel 2, channel 1, channel 2, etc.).

Atom	Characteristics	Remarks
		- Wish: possibility to use “vertical sorter” atom as a “vertical merge”.
A027- Lead Times	Table can be filled from which atom to which atom the leadtime has to be measured.	- Wish: possibility to retrieve the names of the atoms from a pull-down menu (new exact typing is required). - Wish: possibility to group atoms in the table (often, the times from all the check-in blocks to all the carousels are required). - Wish: possibility to export all leading times for further calculations (not only a histogram is wanted, also maximum, minimum, mean, etc.).
A028- Accumulating Conveyor	Similar to “accumulating conveyor”, extended with attributes necessary for the “merge” atom	
A029- Curved Accumulating Conveyor	Similar to “curved accumulating conveyor”, extended with attributes necessary for the “merge” atom	
A030- Buffering Belt Conveyor	A “non accumulating conveyor” atom extended with a stop function	- Shadow in 3d view is incorrect when conveyor is rotated.
A031- Sink	Similar to “sink” atom	
Sample Models		

[1)] Double click on “Baggage” atom in Model Layout window results in error message:

> *1 Atom: A002-Baggage10 (ID=175), onuser>No atom currently selected:setatt(1,ptv(c),atombyname([A001-AtomAttributes],library))*
> *2 Atom: A002-Baggage10 (ID=175), onuser>No atom currently selected:execonuser(atombyname([A001-AtomAttributes]),library)*

Incontrol ED: Bug is fixed.

Appendix J: Attributes of the cost calculator

The following table contains the list of attributes of the cost calculator (filename "VI_LCC_Calculator.atm", to be used in combination with the file named "VI_BAX.atm" in Enterprise Dynamics simulation software). Besides the attribute number and name, the initial values and a short description are given.

Nr.	Name	Initial value	Description
1	CapexTotal	0	Total purchase price in euro of the BHS components and the system controls [integer]
2	MaintenanceTotal	0	Total of maintenance expenditures (including maintenance personnel, spare parts and consumables) during the life cycle in euro [integer]
3	O&Mtotal	0	Total of organisation and management setup expenditures (including documentation, training, O&M equipment and initial spares) in euro [integer]
4	OperationTotal	0	Total of operational expenditures (including control room and handling personnel and energy) in euro [integer]
5	LCCTotal	0	Total expenditures on system from the customers point of view during the life cycle in euro [integer]
6	EnergyValue	0	If true, the energy expenditures will be included in the calculations, if false they will be omitted [boolean]
7	CycleTime	15	Number of years the system will perform its function [real] (range : 0 – 30)
8	CapexValue	1	If true, the capital expenditures will be included in the calculations, if false they will be omitted [boolean]
9	Documentation-Value	1	If true, the documentation expenditures will be included in the calculations, if false they will be omitted [boolean]
10	InitialSparesValue	1	If true the expenditures on initial spares will be included in the calculations, if false they will be omitted [boolean]
11	TrainingValue	1	If true, the employees training expenditures will be included in the calculations, if false they will be omitted [boolean]
12	OperatingTeam-Value	1	If true, the expenditures on the operating team will be included in the calculations, if false they will be omitted [boolean]
13	HandlingTeamValue	0	If true, the expenditures on the handling team will be included in the calculations, if false they will be omitted [boolean]
14	-	-	Not used
15	MaintenanceTeam-Value	1	If true, the expenditures on the maintenance team will be included in the calculations, if false they will be omitted [boolean]
16	SparePartsValue	1	If true, the expenditures on spare parts will be included in the calculations, if false they will be omitted [boolean]
17	OMEquipValue	1	If true the expenditures on setup equipment will be included in the calculations, if false they will be omitted [boolean]
18	OperationDays	365	Number of days that the BHS is operational per year [integer] (range: 0 – 365)
19	EnergyPerc	3	Percentage of the capital expenditures (attribute nr. 1) that will be

Nr.	Name	Initial value	Description
			calculated for the energy cost per year [real] (range: 0 – 1000)
20	DailyHours	20	Number of hours that the BHS is operational per day [real] (range: 0 – 24)
21	TrainingPerc	3	Percentage of the capital expenditures (attribute nr. 1) that will be calculated for the training cost [real] (range: 0 – 1000)
22	DocumentationPerc	1	Percentage of the capital expenditures that will be calculated for the documentation cost [real] (range: 0 – 1000)
23	O&MEquipmPerc	2	Percentage of the capital expenditures that will be calculated for the setup equipment cost [real] (range: 0 – 1000)
24	InitialSparesPerc	3	Percentage of the capital expenditures that will be calculated for the initial spares cost [real] (range: 0 – 1000)
25	SparePartsTotalPerc	0	Percentage of the capital expenditures that will be calculated for the spare parts during the total life cycle [real] (range: 0 – 1000)
26	ConsumablesPerc	0.03	Percentage of the capital expenditures that will be calculated for the consumables (oil, filters, etc.) cost per year [real] (range: 0 – 1000)
27	NrOpManagers	1	Number of operation managers necessary at one time (in the control room), when the BHS is operational [real] (range: 0 – 100)
28	OpManagerCost	100	Hour wage of a operation manager in euro [real] (range: 0 – 1000)
29	NrOpEmployees	2	Number of operation employees necessary at one time, when the BHS is operational [real] (range: 0 – 1000)
30	OpEmployeeCost	60	Hour wage of a operation employee in euro [real] (range: 0 – 1000)
31	NrBagHandlers	14	Number of baggage handlers necessary at one time, when the BHS is operational [real] (range: 0 – 1000)
32	BagHandlerCost	40	Hour wage of a baggage handler in euro [real] (range: 0 – 1000)
33	NrMaintMenFirst	4	Number of maintenance men first line necessary at one time, when the BHS is operational [real] (range: 0 – 1000)
34	MaintManFirstCost	50	Hour wage of a maintenance man first line in euro [real] (range: 0 – 1000)
35	NrMaintMenSecond	1	Number of maintenance men second line necessary at one time, when the BHS is operational [real] (range: 0 – 1000)
36	MaintManSecond-Cost	150	Hour wage of a maintenance man second line in euro [real] (range: 0 – 1000)
37 to 39	SpareParts1 To SpareParts3	0	Percentage of the capital expenditures that will be calculated for the spare parts during the first, second and third year (including overhauls) [real] (range: 0 – 1000)
40 to 66	SpareParts4 To SpareParts30	Vary from 0.5 to 4	Percentage of the capital expenditures that will be calculated for the spare parts during the fourth to thirtieth year (including overhauls) [real] (range: 0 – 1000)
67	ControlsEuro	800000	Purchase price in euro of the system controls (this price will be included in attribute 1) [integer]

Table J.1. The attributes of the cost calculator.

Appendix K: Calculation steps of the cost calculator

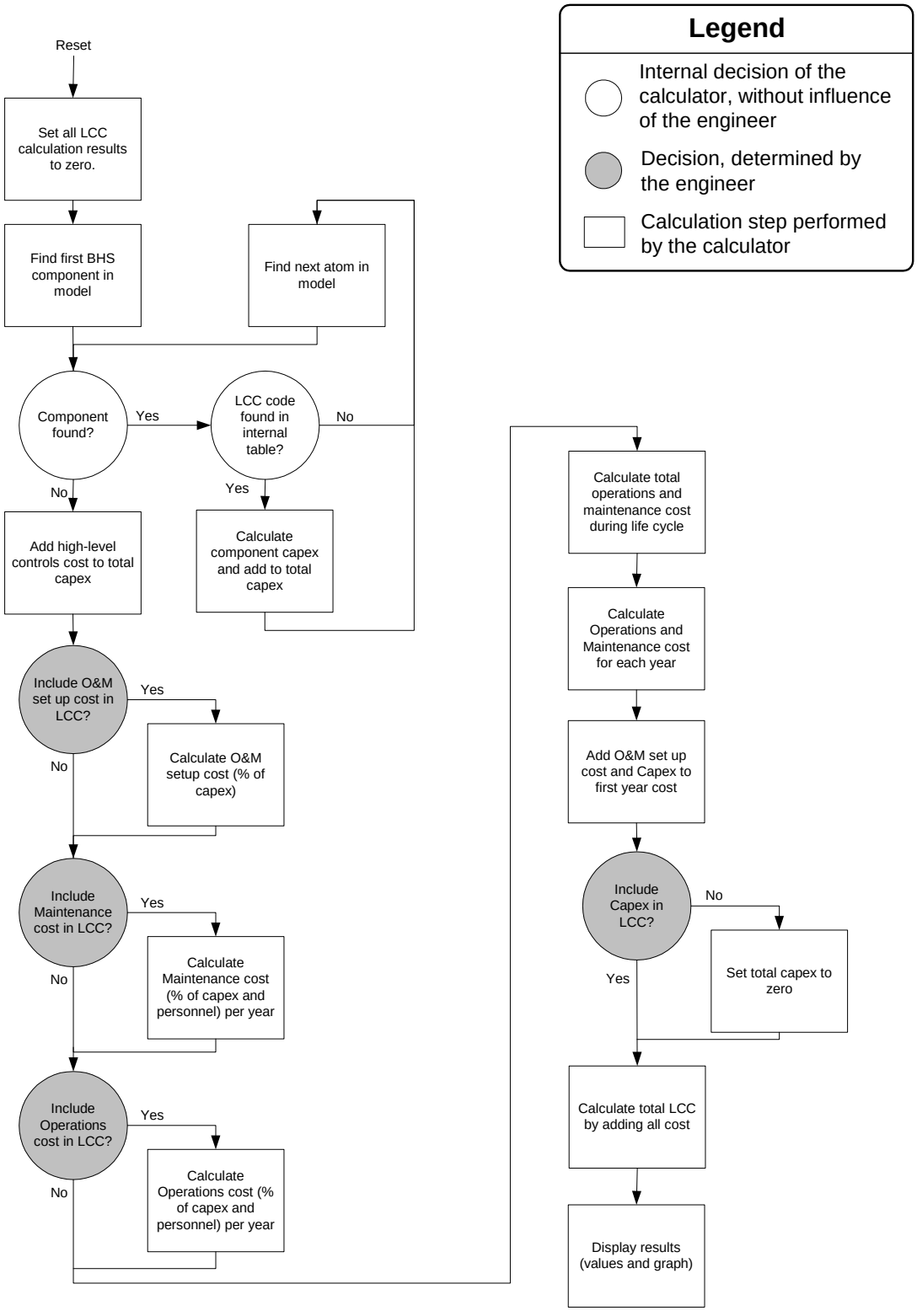

Legend
Internal decision of the calculator, without influence of the engineer
Decision, determined by the engineer
Calculation step performed by the calculator
Reset
Set all LCC calculation results to zero.
Find first BHS component in model
Find next atom in model
Component found?
Yes
No
LCC code found in internal table?
Yes
No
Add high-level controls cost to total capex
Calculate component capex and add to total capex
Include O&M set up cost in LCC?
Yes
No
Calculate O&M setup cost (% of capex)
Include Maintenance cost in LCC?
Yes
No
Calculate Maintenance cost (% of capex and personnel) per year
Include Operations cost in LCC?
Yes
No
Calculate Operations cost (% of capex and personnel) per year
Calculate total operations and maintenance cost during life cycle
Calculate Operations and Maintenance cost for each year
Add O&M set up cost and Capex to first year cost
Include Capex in LCC?
No
Yes
Set total capex to zero
Calculate total LCC by adding all cost
Display results (values and graph)

Figure K.1 The calculation steps of the cost calculator.

Appendix L: Internal table of the cost calculator

External version: CENSORED

The prices mentioned in this appendix are imaginary prices only!!

The table below is included in the "VI_LCC_Calculator.atm" (to be used in combination with the "VI_BAX.atm" in Enterprise Dynamics simulation software. This table contains the data necessary to calculate the purchase prices of all BHS components that are used within a certain system concept.

Before using these prices, read the following remarks:

- All prices are estimated selling to customer prices in euro
- All component prices are with the controls on PLC-level
- All component prices are without the high-level system controls (the high-level control cost can be entered by right-click on the calculator in the ED 2D window)
- All prices are without the "platform / steelwork" (Not included in calculator: when more then one building level is required, 10 up to 15 euro has to be added to the meter prices of all conveyors)
- The required number of start-stop conveyors depends on the way the baggage flow is arranged just before the start-stop conveyors (a steady supply of baggage requires less start-stop conveyors). If applicable, a minimum and maximum number of start-stop conveyors are mentioned in the clarification text below.
- The initials refer to the source of the prices (JGr: Jan Graste, MB: Marcel Bunkers)

LCC Code	Name	CAPEX1	CAPEX2	CAPEX3	CAPEX4
101	Conveyor belt	10 (JGr)	15 (JGr)		
102	Start/Stop conveyor	20 (JGr)			
201	VertiSorter	10 (JGr)			
301	CheckIn Isle	20 (JGr)	25 (JGr)		
401	Triplanar	10 (JGr)	15 (JGr)		
501	Screening machine Level1&2	20 (MB)			
502	Screening Machine Level3	10 (MB)			
601	Automated Coding Station	20 (JGr)			
602	Manual Coding Station	10 (JGr)			

701	TraySorter / Helixorter	20 (JGr)	25 (JGr)	30 (JGr)	35 (JGr)
702	TraySorter Induct	30 (JGr)			
703	TraySorter Chute	35 (JGr)			
801	VertiMerge	10 (JGr)			
802	Sidemerge	20 (JGr)			
901	EBS Conveyors	10 (Maaike Gremmen)	15 (Maaike Gremmen)		

Table J.1. Internal table of the LCC calculator, February 2002.

Clarification of the internal table content.

The first column contains the LCC code that refers to the specific BHS component as mentioned in the second column. These codes are also added as an attribute to the simulation atoms of the BAX Suite (see appendix M). The columns named CAPEX1 to CAPEX4 are different unit prices that are necessary to calculate the total purchase price. The calculation method depends on the concerning BHS component. Each component has an attribute that contains a unique LCC code. Based on this code the LCC calculator finds the right row to be used for the calculation in the internal table. If besides the LCC code another attribute of the BHS component is used, these attributes are also mentioned below:

Conveyor belt

A conveyor belt costs 10 (see table) euro/meter or 15 euro/meter if the speed exceeds the 80 m/min (please note that these prices already include an addition of *** euro/meter to compensate curves). So the calculator uses the attributes length and speed of the conveyor to calculate the capex.

Start-Stop conveyor

A start-stop conveyor costs 20 euro per unit. So, for each start-stop conveyor the calculator finds in the simulation model, it adds 25 euro to the capex.

Vertisorter®

Unit price is 10 euro. So, for each VERTISORTER® the calculator finds in the simulation model, it adds the unit price to the capex. This sorter always needs 3 start-stop conveyors!

Check-In Isle

Each desk (including desk, weighing belt and dispatching belt) costs about 20 euro (the desk is obtained from a subcontractor, approximately *** euro per desk). The collector belt behind the desk costs about 25 euro/meter. The calculator uses the attributes containing the number of desks and the length of the collector belt.

TRIPLANAR®

A TRIPLANAR® flat make-up costs 10 euro/meter. A tilted TRIPLANAR® costs 15 euro/meter. Therefor the calculator uses, besides the length, an attribute that indicates whether it's a flat or tilted TRIPLANAR®.

Screening machines

A screening machine level 1&2 costs 20 euro per unit. A level 3 machine costs 10 euro per unit (obtained from subcontractors). The screening machines require a minimum number of start-stop conveyors of 1 and a maximum number of 4.

Coding stations

A handgun (manual) costs 10 euro per unit. An automated 3-directional scanner costs 20 euro per unit. The scanning machines require a minimum number of start-stop conveyors of 1 and a maximum of 4 (depending on the regularity of the supplied baggage flow).

Traysorter / HELIXORTER®

A traysorter costs 20 euro/meter. If it concerns a HELIXORTER® the price is 25 euro/meter. Each induct costs 30 euro per unit and each chute costs 35 euro per unit. So the calculator uses attributes that indicate the length and the type of the traysorter. It also counts the number of chutes and inducts and adds the unit prices to the capex. An induction point always needs start-stop conveyors (maximum of 4 when the maximum capacity is required).

Traysorter Induct and Chute

The induct price of 30 euro per unit and chute price of 35 euro per unit are included in the table twice (see also the Traysorter / HELIXORTER®). This is done for programming reasons, because the chute and induct atoms can be placed in both the "model-atom" and the "traysorter-atom".

VertiMerge

A vertimerge costs 10 euro per unit (compare with VERTISORTER®). For each vertimerge found in the model, the calculator adds the unit price to the capex. A vertimerge always needs 6 (!) start-stop conveyors.

Sidemerge

A side merge unit, including one start-stop frequency conveyor, costs 20. For each unit the calculator finds, this unit price is added to the capex. A minimum of two additional start-stop conveyors is required.

EBS Conveyors

Conveyors with loose baggage cost 10 euro/meter (one bag takes 1 meter) and conveyors with tubs cost 15 euro/meter (one tub takes 1.2 meter). Each tub costs *** euro. So the calculator uses attributes that indicate the number of bag positions in the EBS and whether it concerns an EBS with or without tubs.

Appendix M: Adjustments of the BAX Suite objects

In this appendix the objects (in ED called atoms) in the BAX Suite Version 01-b (part of the Airport Suite, see appendix G) are described, which had to be adjusted in order to use the cost calculator (filename "VI_LCC_Calculator.atm") in the Enterprise Dynamics simulation software. The total set of atoms, including the adjusted atoms, are saved in the file "VI_LCC_BAX.atm". The adjusted atoms have new names to make distinction with their originals possible.

Original atomname	New atomname	Adjustments	Reason for adjustment
A006-Carousel	VI Carousel	1) Added attribute: "LCC_Code" "Tilted" 2) On userevent: added menu option, "Tilted or not"	Identification and component price calculation, which depends on whether the carousel is tilted or not
A007-Check-in Block	VI CheckIn Isle	1) Added attribute: "LCC_Code" "NrDesks" "Collectorlength" 2) On userevent: added menu options, "Number of desks" and "Collector conveyor length"	Identification and component price calculation, which depends on the number of desks and the length of the collecting conveyor
A009-Manual Encoding Station	VI Manual Coding Station	1) Added attribute: "LCC_Code"	Identification
A010-Fast Non Accum. Conveyor	VI Belt Conveyor	1) Added attribute: "LCC_Code"	Identification
A014-Merge Normal	VI SideMerge	1) Added attribute: "LCC_Code"	Identification
A016-Automatic Encoding Station	VI Automatic Coding Station	1) Added attribute: "LCC_Code"	Identification
A017-Screening Machine	VI Screening Level1&2	1) Added attribute: "LCC_Code"	Identification
A017-	VI Screening	1) Added attribute:	Identification and distinction

Original atomname	New atomname	Adjustments	Reason for adjustment
Screening Machine	Level3	"LCC_Code" 2) Color in 2D view	with VI Screening Level1&2
A019-Sorter Discharge	VI TraySorter Chute	1) Added attribute: "LCC_Code"	Identification
A020-Sorter Induction	VI TraySorter Induction	1) Added attribute: "LCC_Code"	Identification
A024-Tray Sorter	VI TraySorter	1) Added attribute: "LCC_Code" "Helixorter" "NrChutes" "NrInductions" 2) On reset event: added counting function for the number of inducts and chutes in the TraySorter atom 3) On user event: added menu option, "Helixorter or not"	Identification and component price calculation, which depends on the number of chutes, the number of inducts and whether it is a normal traysorter or a Helixorter. The component price includes the inducts and chutes, so they have to counted in both the model atom and the VI TraySorter atom.
A026-Vertical Sorter	VI VertiSorter	1) Added attribute: "LCC_Code"	Identification
A028-Accumulating Conveyor	VI Start/Stop Conveyor	1) Added attribute: "LCC_Code" 2) Initial length set to 1.5m	Identification and more realistic length
A014-Merge Normal	VI Vertimerge	1) Added attribute: "LCC_Code" 2) Color and size in 2D view	Identification and distinction with SideMerge
A022-High Aggregation Storage	VI EBS	1) Added attribute: "LCC_Code" "Tubs" 2) On user event: added menu option, "stored in tubs or not"	Identification and component price calculation, which depends on whether the bags are stored in tubs or not.

Table M.1. The adjustments on the BAX atoms (objects).

Appendix N: Cost estimation guidelines

External version: CENSORED

The numbers in this appendix are hidden and represented as ***

The way the capital expenditures (capex) are calculated is explained in appendix L. The capex are not further detailed in this appendix. The labour cost depend on the number of operational hours per year and the cost per employee per hour. Concerning the other distinguished LCC elements, percentages of the capex are used. The following data and sources might be guiding in finding the right percentages to use. ***Note that these are very rough estimations that always have to be verified!***

Training cost
There is no data available. Depends on the chosen training facilities. The concept "train the trainer" costs less labour hours than the "train all involved employees" concept.

Documentation cost
There is no data available. Again the number of hours spend on documentation depend on the complexity of the system and the required documentation detail.

O&M equipment cost
The equipment necessary to use and maintain the BHS depends on the systems complexity. A small system with standard components will need no special equipment. More complex components (and therefor higher capex) require special (and therefor more expensive) equipment. Probably the relation between the capex and the cost of setup equipment will be an S-curve (source: AAa).

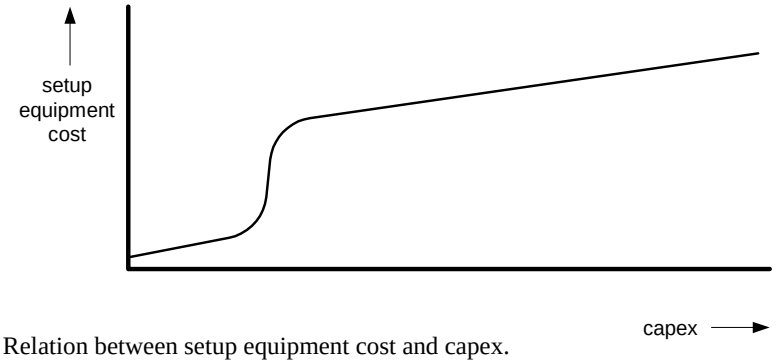


Figure N.1. Relation between setup equipment cost and capex.

Initial spares cost
A system with a lot of different BHS components requires many different initial spare parts. The more unity in the components, the less different spare parts necessary. The following graph shows a relation between the percentage of the capex needed for initial spare parts and the capex (source: document 06320.005141, HKo). Based on this graph the following assumptions can be made towards the initial spare cost:

Capex < *** euro, initial spares ***% of capex
*** euro < Capex < *** euro, initial spares ***% of capex
Capex > *** euro, initial spares ***% of capex

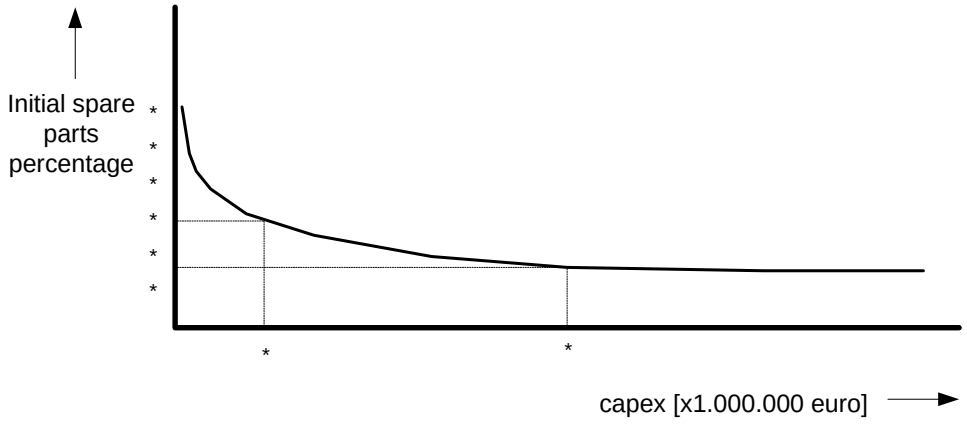


Figure N.2. Relation between the percentage of capex for initial spares and capex.

Consumables cost
Based on calculations for one project, the consumables cost about ***% of the capex per year (source: document CAAS/T3BHS&TBS-version 1, AAa).

Energy cost
There is no data available. Estimation based on studies performed by RvP is ***% of capex per year (source: RvP).

Spare parts cost
The first years after the start up and test period of the BHS hardly any spare parts are necessary. Most BHS components have a technical life time from *** to *** operational hours (source: document 1.6320.03346 Hko). Transform this in a life time in years:
Example:

Life span	: 35.000 hours
Operational days per year	: 365
Operational hours per day	: 20
% of time in operation	: 80

Results in a technical life time of (35.000 / (365 * 20)) / (80 / 100) = 6 years

This means that the required number of spare parts will increase after approximately 5 years and peak after 6 years. This cycle will repeat itself and therefor another peak can be found after approximately 12 years. If for some reason the use of the system is less than the mentioned 20 hours per day, the pattern will shift further in time.

An estimation of the total percentage of capex needed for spare parts (including overhauls) for one project over 16 years is ***% (source: document 1.6320.03346.V, HKo). According to RvP this will be more for a average project (estimation of ***% over 20 years).